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INVESTIGATIONS

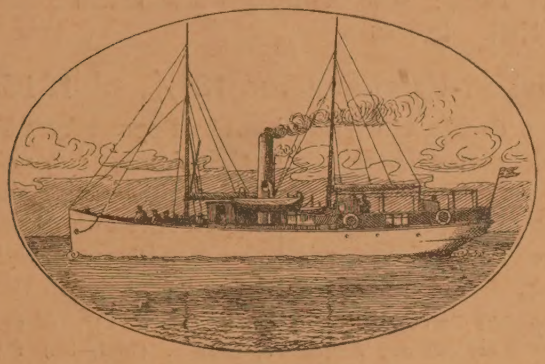
Report

of

The Danish Biological Station

to

The Board of Agriculture.



XXXI.

1925.

By

C. G. Joh. Petersen,
Ph. D., L. L. D., D. Sc.
Director.

Copenhagen.
In Commission by G. E. C. Gad.
Centraltrykkeriet (C. Ferslew).
1926.

C. G. Joh. Petersen: Om de skalbærende Molluskers Udbredningsforhold i de danske Have indenfor Skagen 1888. 8°. 162 pg. 2 Kort.

Det videnskabelige Udbytte af Kanonbaaden »Hauch«s Togter i de danske Have indenfor Skagen. 1893. 4°. 464 pg. Atlas i folio.

Indhold: Echinodermata (Petersen), Diatomeer (Cleve), Undersøgelse af nogle Bundprøver (Rørdam), Mollusca (Petersen), Cephalopoda (Posselt), Crustacea malacostraca (Meinert), Hydrografi (Rørdam), Polyzoa (Levinsen), Ascidiæ simplices (Traustedt), Annulata, Hydroidæ, Anthozoa, Porifera (Levinsen), Nogle alm. Resultater (General Results, Engl.) (Petersen).

C. F. Drechsel: Oversigt over vore Saltvandsfiskerier med Kort og Planer. 1890. 4° 100 pg. Med et Tillæg: »Om Naturforholdene indenfor Skagen« af *C. G. Joh. Petersen.* Med Kort. 4°. 46 pg.

Fiskeri-Beretning for $18^{88}/_{89}$ til 1916.

Beretninger fra den danske biologiske Station findes paa dansk publiceret i de tilsvarende Fiskeri-Beretninger, til Beretning XXI med Tillæg. Senere udgives de som selvstændige Publicationer paa Dansk og paa Engelsk.

The Reports from The Danish Biological Station are also published in Danish in the corresponding Fiskeri-Beretning, until Report XXI with Appendix. Later on they are specially published in Danish and in English, but not in the Fiskeri-Beretning.

I. Fiskenes biologiske Forhold i Holbæk Fjord. (1890—91.)*) 63 pg. Med et Kort.
II. Om vore Kutlingers *(Gobius)* Æg og Ynglemaade. (1891—92.) 9 pg. Med 2 Tavler.
II. On the Eggs and Breeding of our Gobiidæ. (1891—92.) 9 pg. Two Plates.
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III. The Pelagic Life in Fænø Sound etc. (1892—93.) 38 pg. Tables.
IV. Om vore Flynderfiskes Biologi og om vore Flynderfiskeriers Aftagen. (1893—94.) 146 pg. 2 Tavler. 1 Kort og mange Tabeller.
IV. On the Biology of our Flat-fishes and on the decrease of our Flat-fish Fisheries. (1893—94.) 146 pg. 2 Plates. 1 Chart. Many Tables.
V. Den alm. Aal (*Anguilla vulgaris* T.) anlægger før sin Vandring til Havet en særlig Forplantningsdragt. (1894—95.) 35 pg. Med 2 Tavler.
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V. The common Eel (*Anguilla vulgaris* T.) gets a Particular Breeding-dress before its Emigration to the Sea. (1894—95.) 35 pg. With 2 Plates.
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VI. Om Rødspætteyngelens aarlige Indvandring i Limfjorden etc. (1895—96.) 49 pg. 1 Kort. 2 Tabeller.
VI. The Yearly Immigration of young Plaice into the Limfjord etc. (1895—96.) 48 pg. 1 Chart. 2 Tables.
VII. Plankton-Studier i Limfjorden. (1896—97.) 23 pg. 1 Kort. 4 Tabeller.
VII. Plankton-Studies in the Limfjord. 1897. 23 pg. 1 Map. 4 Tables.
VIII. Om et Skovl-Vaad til Undersøgelse af dybere Farvande. (1897—98.) 24 pg. 10 Figurer.
VIII. An Otter-Seine for the Exploration of Deeper Seas. 1898. 24 pg. With 10 Figures.
IX. Travlinger i Skagerak og det nordlige Kattegat i 1897 og 98. (1898—99.) 56 pg. 1 Kort.

*) Tallene i ( ) betegner Fiskeri-Beretning for nævnte Aar.

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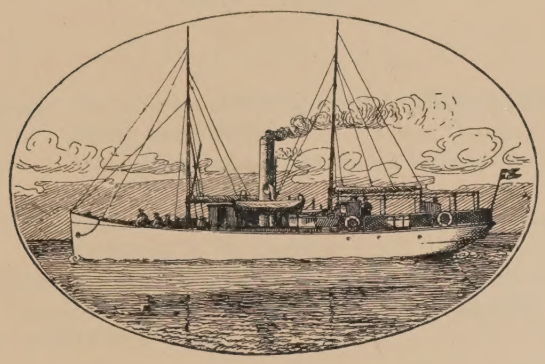

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CONTENTS

		page
I.	*C. G. Joh. Petersen*: The Influence of Fishing upon the Stock of Plaice in the Baltic during recent Years	5
II.	„ „ : Investigations on the Size of the Stock of Oysters in the Limfjord 1924	13
III.	„ „ : Report to the Ministry of Agriculture concerning increased Motor-Fishing in the Limfjord	21
IV.	*H. Blegvad*: Continued Studies on the Quantity of Fish-Food in the Sea Bottom	27
V.	*R. Spärck*: A Comparison between the Danish Oyster-Beds and those in Holland and the South-West of France	57

I.

The Influence of Fishing upon the Stock of Plaice in the Baltic during recent Years.

By

C. G. JOH. PETERSEN.

In Report 29 from the Danish Biological Station, published in 1922, I advised on pg. 27 that the question of protection for the plaice should be considered, for instance in the Beltsea, presuming it however desirable to watch events for a while, especially in order to make certain, whether the big annual yield in kg would decrease during the years after 1921. This is what has now taken place. The yields of the Belts and the western Baltic were in

1919:	2997	tons	of plaice
1920:	2380	–	–
1921:	2036	–	–
1922:	1904	–	–
1923:	1624	–	–

This is based upon the official statistics which surely in the main show the true conditions; in 1924 the yield will undoubtedly be still smaller*). We thus see that since the war there has been a steady decrease in the annual yield. This corroborates my experience among the fishermen and corresponds perfectly with our own fishery experiments and other investigations (See Report 29).

I therefore think that the time has come for a suitable protection of the plaice in the Beltsea, and if possible by the aid of international legislation also in the Kattegat and in certain parts of the Baltic. I shall not, however, dilate upon this side of the matter, but shall procede immediately to discuss some investigations made by the Danish Biological Station in the western Baltic during the years 1921 – 24, i. e. during the years when the stock of plaice owing to intense fishing has undergone such great alterations. Of course it was not easy to foresee the phenomenon of a complete change as to number, weight and age of the stock of plaice, as we do not know in advance the intensity with which such waters will be exploited; it was therefore more of a chance or perhaps caused by certain anticipations that I, during the years in question provided a series of studies indicating the alterations which have taken place, but those studies only cover a small area i. e. the mud-area, 20 – 24 m deep, which is situated abt. 6 – 7 miles E.S.E. of „Hestehoved" on Falster and south of Möen. On table I pg. 10 the result of these studies is shown.

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*) The Fiskeridirektorat has kindly stated that it only reached 1280 tons.

In order to get a survey of the condition of the stock of plaice in former days, I have in the first column given some measurements of plaice made in 1908 and 1909 by Professor Reibisch (See Report 29 f. i. pg. 12), in the following 4 colums our investigations from the years 1921—24 are shown. In all the columns the size and the age of the plaice are indicated, those older than 5 years being put in one group as here the determination of age is rather uncertain.

A glance at this table will show:

1) That no such big plaice of the size 34—39 cm as were found in 1908—09 were taken in 1921—24; they are evidently very rare now, but the majority of plaice in 1924 are longer than 25 cm, and comparatively few are below this size though we have fished with a small-meshed otter-seine with a fishing capacity for plaice down to 8 cm and less.

2) The old small plaice of 14—22 cm have become very rare. The bulk of the stock consists now of 5 year old and younger plaice. This state of things has developed since 1921 during the years 1922—23—24 especially in the years 1923—24. We must keep in mind that very intense fishing has taken place during these years in the Baltic, carried on by Danes as well as by Germans and Swedes.

3) While the 3-years old plaice in 1908—09 and as late as 1921—22—23 were far from reaching a length of 25 cm the majority of the 3 years old plaice are in 1924 somewhat over 25 cm in length and so it is with the 4 and 5 years old plaice. The rate of growth of the plaice has thus increased considerably and is higher in 1924 than before, so that a size limit of 25—26 cm might well be introduced in this water.

4) What does not, however, appear from the table itself is the diminished density of the stock of plaice during the last years; this however is known to us from investigations carried out year after year with the same fishing implement i. e. a small-meshed otter-seine with about 40 m. towing bridle and lines 20 m. long from otter to seine. See Note to the table on pg. 11. In 1921 we took with this implement on a average 100 plaice in each haul of 15 minutes, in 1922 we only took 23 plaice, in 1923 11, and in 1924 only 4 plaice; so that during the last two years 1923—1924 we were forced to buy plaice from the fishermen in order to get enough without spending too much time on fishing, the fishermen's implements being of a higher fishing intensity than ours of a less modern type. In August 1924 we had to change our implements in order to get any plaice at all for investigations. Thus, where we in 1921 took 100 plaice on an average, we only got 4 in 1924, which proves that the density of the stock has gradually become enormously diminished, a fact that the local fishermen are well aware of. Without doubt it is this thinning of the stock that has caused the higher growth-rate in 1924. The dab has undergone the same degree of thinning, from on an average 100 in 1921 to 6—7 in 1924, gradually falling off during 1922—23. Se Note pg. 11.

It might have been well if similar investigations had covered greater areas of

the Baltic, perhaps they have been made by others, but those to hand seem to me to be clear enough, at least with regard to this water, and surely the results apply to great parts of the Baltic, though perhaps not yet for all parts. They show fairly well the alterations of the stock here, and we understand why the quality of the plaice is now better here than it was formerly; we deal now with young plaice of a high growth-rate.

5) It is strange to see how few young plaice of 0, one and two years old, we took during those investigations (see table I), neither in 1908—09 did we take many. I wish however to state, that in 1924 we found an area of shallower water, abt. 8—12 m deep, near „Tolken" at the entrance to the „Grønsund" where we could fish without touching stony ground, and there we found a rather large I-group, but only few 2 years old and none at all from the 0-group; off Stevns light we also on the 2' of August 1924 found a large I-group but only a few plaice belonging to the II-group. In the bay at Køge and in the Sound north of Copenhagen we took in 1924 next to no plaice younger than the III-group, but in both places we found a large IV-group. Near Falster it was the V-group that predominated in 1924; this large group may be traced back through the years 1923—22—21; in this last year it was found as II-group and always as the most numerous group.

It may therefore appear as if fry were only plenty in certain years in the Baltic, but how often this occurs we do not know. Perhaps there is a long interval between such good years, and perhaps the fry do not originate from eggs actually hatched in the Baltic. The degree of renovation of the stock of plaice in the Baltic is therefore doubtful when the present stock has been fished up. The stock will hardly be renewed as quickly as in other waters. The fate of the plaice-fishery in the Baltic is therefore very uncertain.

The 0-group of plaice in the bottom-stage has very rarely been met with in any number in the Baltic and nearly never in shallow water near the sandy beaches where in other waters they usually are to be found. The numerous V-group near Falster in 1924 (plaice hatched in 1919) was however not met with during our investigations in 1924 off Stevns i. e. near the southern limit of the Øresund, but here we found a numerous IV-group, together with a I-group and traces (4 individuals) of a 0-group; but in the bay of Køge and in the Sound north of Copenhagen, as stated above, we met with next to no plaice younger than group III. Thus the conditions seem to differ at Falster and in the Sound.

These investigations have only been sporadic, as so much other work occupied our time, it would therefore be very desirable if before long the old important question of the renovation of the stock of plaice in the Sound and the Baltic in the years to come might be examined methodically over larger areas.

We have not in other Danish waters met with such big changes in the number of individuals in the different age-groups in the different years; the younger age-groups are as a rule always more numerously represented while the older age-groups become more and more scarce, with their increasing years.

Table I.

Age and size of plaice from the Baltic between Falster and Møen.

	East of Falster. *Reibisch.* Aug.1908—Oct.1909						E.S.E. of Hestehoved (Falster), depth 20–24 m																	
							20. Aug. 1921.						16. May 1922.						8. Aug. 1923.						23. July, 5. og 16. Aug. 1924.					
	I	II	III	IV	V	Older	I	II	III	IV	V	Older	I	II	III	IV	V	Older	I	II	III	IV	V	Older	I	II	III	IV	V	Older
8							1																		2					
9																														
10							2													1										
11			1					4						1						2										
12		2					2	6						3												1				
13			5					14						3												3				
14			5	1				20	1						3															
15			7	2	3			26	8						10															
16			5	5	4	3		19	7	1	2				5	1					2					1				
17			6	7	5	3		5	8						6	3					3									
18			1	6	7	7		1	14	1	2	5			7	3					4									
19				3	15	24		1	7		2	4				3					2	4								
20			1	3	5	35			2	2	2	12			1	3	1					1					1			
21				2	2	47			3		1	3				4		1			2	2					.	2		
22					1	75				1		5				1		3			1	9						1	1	
23					2	74						3				4	1	2			1	2	1	1			1	2		
24					5	54				1	1	3					1	6				3	2						4	1
25				1	2	47					1						1	4				6	1				3	5	7	
26						36					2							6				2	1				6	18	19	1
27				1		14												2									3	5	13	4
28				1		12												1					1				2	2	12	5
29						13												1									6	2	3	2
30						9												2										5	8	1
31						3												1											5	3
32						4																						1	1	
33																													1	
34						1																								
35						3																								
36						1																								
37						1																								
38						1																								
39						1																								
40																														
	2	31	32	51	468		5	96	50	6	13	35	7	32	22	4	29		3	15	29	6	1		2	5	22	43	74	17
	Total 584 ind.						Total 205 ind.						Total 94 ind.						Total 54 ind.						Total 163 ind.					

82 + 81

Notes to Table I.

The plaice in 1908—09 were taken by Reibisch with different implements. The plaice in 1921—22 were all taken by ourselves with a small-meshed otter-seine; in 1923 we only took 22 plaice this way, the ages of two of which were not determined, the other 34 we bought from a fisherman; in 1924 we took 82 plaice with a small-meshed otter-seine, partly with short, partly with long lines, while the remaining 81 were bought from a fisherman.

In 1908—09 Reibisch determined plaice up to 17 years old; in the later years we have not been able to determine plaice older than about 10 years, but the age determinations for these old fish are often not reliable.

In the years 1921—24 the yields of our hauls made with small-meshed otter-seine and short lines i. e. the length of the towing bridles 40 m each, and the lines from otter to seine 20 m each, were as follows:

										The average per 15 min:
1921:	1	haul,	15	min.,	150	plaice	and	115	dab.	103 plaice and 103 dab.
„	1	„	„	„	55	„	„	90	„	
1922:	1	„	20	„	31	„	„	96	„	23 „ „ 72 „
1923:	1	„	15	„	13	„	„	13	„	11 „ „ 15 „
„	1	„	„	„	9	„	„	16	„	
1924:	1	„	15	„	4	„	„	4	„	4 „ „ 7 „
„	1	„	„	„	4	„	„	9	„	

II.

Investigations on the Size of the Stock of Oysters in the Limfjord 1924.

By

C. G. JOH. PETERSEN.

In the following report on the enumeration of oysters by diving in the Limfjord during the summer 1924 sent to me by Mag. R. Spärck it is stated, that diving has been untertaken at 47 places and that the oysters have been enumerated in each place.

The spat is very scarce and there are but few small oysters, so that the enumerated oyster were nearly all over 7 cm. In order to draw a comparison between the size of the stock now and in 1907, from which year we have in Report 17 from the Danish Biological Station an account of enumerations from divings made in order to get an estimate of the size of the stock, unknown till then, it is best to compare the density of the oysters found those two years at the sea bottom by the divers. As no reliable measuring of the areas of the oyster beds exists, partly because these areas change and partly because they are not very well known, the figures concerning the absolute size of the stock are very uncertain, but the stated densities show clearly enough the decline from 1907 to 1924.

The figures from 1907 were all given in feet and refer to the true oyster-beds; they can therefore best, transposed into meters, be compared with the 1924 figures from the areas of hard bottom; therefore we only use those in the comparison.

The oysters taken in 1924 may as we have already stated best be compared with the oysters taken in 1907 of 7 cm and more (Table III a in Report 17 pg. 20). Below we state for 4 of the more important broads the area in m^2 investigated for each oyster taken.

	Area in m^2 per 1 oyster in 1907 and 1924.	
The broads of Livø, Løgstør og Risgaard.....	1,49 m^2	58 m^2,
The broad of Thisted.....	3,94 „	57 „
The bay of Venø and the broad of Kaas.....	1,47 „	13 „
The broad of Nissum	6,06 „	24 „

Average: 1 oyster per 3,24 m^2 in 1907, and 1 oyster per 38 m^2 in 1924.

We see at once, that we must count many more m^2 of bottom area per 1 oyster in 1924 than in 1907. If we count an average of the divings during the two years, we find 1 oyster per each 3,2 m^2 in 1907, but only 1 per each 38 m^2 in 1924. The density has thus decreased to abt. $^1/_{12}$.

The approximate calculation for the area, on which investigations in 1907 were based gave with this density abt. 90 Millions oysters from the whole of the Limfjord; the corresponding figure should thus now be abt. 7,5 Millions, and we are certainly not far wrong if we estimate the present stock of oysters above 7 cm to be between abt. 5 and abt. 10 millions; but in 1907 there were, moreover, a lot of small oysters below 7 cm which were nearly completely absent during the investigation of 1924.

We were already familiar with this big decrease in the stock of oysters from the daily yield of oysters from the dredging boats, the yields having gone down steadily during the years from 2—3000 to a few hundred per day.

During the divings in 1924 we took not only all the living oysters on the area but also those newly dead, easily distinguishable by the fact that the ligament still binds the shells together and that these are clean and without any growth on the inside. On enumerating those newly dead oysters we saw, that the death-rate for the season 1923—24 reached abt. 70 % of the stock in some parts of the broad of Livø, in other parts of the same broad it reached 65,40 and 22 %, in the Thisted Broad it reached 58 and 60 %, but in the bay of Venø only 20 % and in the broad of Nissum abt. 30 and 40 %, so that we are not far wrong in estimating that about half of the stock of full grown oysters in the Fjord died during the severe winter 1923—24, and that the death-rate has been greatest in the inner broads and less in the western ones.

Report sent to the Director of the Biological Station concerning the Enumeration of the Stock of Oysters in the Limfjord during the Summer of 1924.

By R. Spärck, Mag. scient.

General Remarks.

All the dredgings and divings mentioned in this report have been made on areas where fishing for oysters has been carried out during the later years. It was quickly seen, that we had to deal with two kinds of areas of essentially different density, i. e. areas with hard bottom, as a rule inside the 6 m line, and areas with soft bottom, as a rule outside the 6 m line. We have therefore fixed a special average density for each of these areas in the different parts of the Limfjord.

In addition to the living oysters the diver has also taken shells of dead oysters. I made him to do this in order to get a survey of the death-rate, which

has been abnormally great for some parts of the Fjord during the winter 1923—24. The shells of oysters dead since the summer 1923 could easily be distinguished from the others, partly because their shells were still joined together and partly because they were clean and white on the inside. Open shells which have been left in the Fjord for one summer are all covered by barnackles, worm-stubes and other such organisms. These shells of newly dead oysters have then been counted and measured in the same manner as the living oysters.

The areas investigated by the diver were measured by the diver on the sea-bottom measuring with a line the radius from where he had gone dow, and as far as he could reach with his air hose. For all the divings the length of the hose was 18 m. The radii differed a little, as the anchored boat never kept absolutely on the spot. In such cases we hawe taken an average.

If as a rule we have undertaken more divings on the areas with hard bottom that on the areas with soft bottom, though the latter are the larger, it is partly because much the larger part of the oyster-stock is found on the areas with hard bottom, partly because the density on soft bottom is so small, that by diving investigations we find very few or no oysters at all. For better orientation we have therefore undertaken some dredgings on the soft bottom. The areas dredged have been measured by fixing the position of the boat and marking it on the chart at the beginning and at the end of the dredging and the distance has thus been measured. The area is found by multiplying this distance by the width of all the dredges together. In this way very large areas may be investigated in comparatively short time, and, in spite of a small density, it is possible to get some oysters.

The Western Parts of the Broad of Livø.

In this part of the Fjord divings were undertaken at 15 places. Of these divings 6 were made on hard bottom (6 m and less), 9 on soft bottom (more than 6 m).

The Hard Bottom Area.

Locality	Area	Number of living	Number of newly dead
Bukser Odde	1018 m²	24	32
Langegrund	775 -	1	11
Galegrund	858 -	9	40
Hundrup	858 -	0	0
Grønne Bakke	805 -	12	41
Tødsø Hage	908 -	17	28
Total	5222 m²	63	152

The average density on this area thus equals 1 oyster to 83 m².

The death-rate during the season 1923—24 amounts to 71% of the stock.

The Soft Bottom Area.

Locality	Area	Number of living	Number of newly dead
Draaby Vig	616 m²	1	6
Fegge Røn	755 -	2	3
Amtoft Rev	707 -	0	0
Holmtange Hage	707 -	0	0
Between Langegrund and Hethavn	572 -	2	3
Langegrund	660 -	1	2
Livø	572 -	2	0
Blinde Røn	660 -	0	0
Blinde Røn	550 -	4	8
Total	5799 m²	12	22

The average density of this area was thus 1 oyster to abt. 484 m².

The death-rate during the season 1923—24 amounts to 65 % of the stock.

For further orientation we undertook 5 dredgings covering a soft bottom of 54,000 m². We took 27 living and 45 newly dead oysters. This gives at least a density of 1 oyster to 2000 m², and a death-rate during the season 1923—24 of 62 % of the stock.

The Eastern Part of the Broad of Livø

(with Risgaard Broad and Skive Fjord).

In this part we have undertaken 13 divings, 8 on hard bottom and 5 on soft bottom.

The Hard Bottom Area.

Locality	Area	Number of living	Number of newly dead
Flovtrup	908 m²	53	17
Fursund	805 -	17	3
Nakken	616 -	14	2
Ertebølle	755 -	11	1
Trend	805 -	8	7
Engelst Odde	707 -	25	7
Risgaarde	1070 -	7	3
Hvalpsund	805 -	4	0
Total	6471 m²	139	40

The average density on this area is thus 1 oyster on 47 m².

The death-rate during the season 1923—24 is 22 % of the stock.

The Soft Bottom Area.

Locality	Area	Number of living	Number of newly dead
Skive Fjord	660 m²	0	0
Rotholm	660 -	2	0
E. of Livø	755 -	0	0
Livø Tap	755 -	0	0
Livø Tap	720 -	0	0
Total	3550 m²	2	0

For further orientation 2 dredgings were undertaken on the soft-bottom area. More than 22,000 m² were dredged. We took 29 living and 19 newly dead oysters. This indicates a somewhat greater density, than the one fixed from the divings, i. e. 1 to abt. 760 m². From the divings we found 1 to abt. 1770 m². With the aid of the dredges a death-rate vas found of abt. 40 % during the season 1923 – 24.

Thisted Broad

(with Visby Broad).

In this part of the Fjord we made divings at 5 places, 4 on hard bottom, 1 on soft bottom.

The Hard Bottom Area.

Locality	Area	Number of living	Number of newly dead
Skærbæk	755 m²	9	13
Hanklit	770 -	6	15
Silstrup	707 -	17	12
Faartoft	650 -	19	30
Total	2882 m²	51	70

The average density on this area is thus 1 oyster per 57 m².

The dead-rate during the season 1923—24 is 58 % of the stock.

The Soft Bottom Area.

We made the divings in the middle of the broad. Area 550 m². We took 1 living and 4 newly dead oysters.

For further orientation we undertook 2 dredgings on the soft bottom area. Area 29,000 m². We took 10 living and 15 newly dead oysters. This gives a density of 1 to 2900 m², and a death rate during the season 1923 – 24 of 60 %.

The Bay of Venø.

(with Kaas and Lysen Broad).

On this locality 4 divings were made, all on hard bottom.

Locality	Area	Number of living	Number of newly dead
Nygaards Hage	707 m²	1	5
Nygaards Hage	707 -	5	3
Hanbjerg	707 -	199	40
Kaas Hoved	707 -	8	7
Total	2828 m²	213	55

The average density on this area is accordingly 1 oyster to 13 m².
The death-rate during the season of 1923–24 is 20 % of the stock.

On the soft bottom area we undertook for further orientation 2 dredgings covering 22,000 m². We only found 4 living oysters and no newly dead. The density seemed very sparce, 1 oyster to abt. 5000 m².

Nissum Broad.

In this part of the Fjord we undertook 10 divings in all, 8 on hard bottom, 2 on soft bottom.

The Hard Bottom Area.

Locality	Area	Number of living	Number of newly dead
Draget	720 m²	9	7
Røjensø Odde	908 -	45	9
Lemvig Røn	755 -	2	0
Flovlev	805 -	5	5
N. Nissum	858 -	39	19
Flovlev	858 -	28	15
St. Knæ	870 -	140	63
Toftum	820 -	4	2
Total	6594 m²	272	120

The average density on this area is thus 1 oyster to 24 m².
The death rate during the season of 1923–24 is 31 % of the stock.

The Soft Bottom Area.

We made two divings. We did not get any living oysters and only 1 newly dead. In order to be better orientated concerning the density, we undertook two dredgings covering an area of 25,000 m² in all. By this we took 54 living oysters and 9 newly dead ones. This indicates a density of at least 1 to 500 m². Judging by these dredgings the death-rate on the soft bottom area during the season of 1923 - 24 should amount to 14 % of the stock.

III.

Report to the Ministry of Agriculture concerning increased Motor Fishing in the Limfjord.

By

C. G. JOH. PETERSEN.

On the subjoined case Ref, L. F. J. 1924 Nr. 418[1] (4 Akts) letter No 2847 regarding increased Motor-Fishing in the Limfjord, I have to make the following comments:

From the subjoined statistics pg. 26 of Fiskeri-Beretningerne it may be seen, that the weight (in kilos) of the yield of plaice (flat-fish) and eel fisheries in the Limfjord have varied a good deal since the year 1898, this among other reasons on account of the varying quantity of fish-food in the cold and warm years (see the Biological Station's investigations on valuation); there is, however, as yet no sign that the intense Motor-Fishing of recent years has increased the weight of the yield noticeably. For many years, apparently each year everything has been caught which during the current year has grown from „undersized" to „eatable" fish. For this reason the fishery-legislation up to the present time has tried to keep the local fisheries as a sort of domestic industry, employing a great number of people with small expense, because for instance their netproceeds are increased when amortization of expensive machinery and cost of petrol can be avoided. It is surely alone the high prices of plaice and eel in recent years that have been able to balance the heavy expences of motor-fishing, and at the same time have forwarded its development, although the yield in weight has not been substantially increased. As regards the eel fisheries, it is all the more strange that they have experienced no succes, as during the last twenty years large silver-eel fisheries with traps and pound-nets have been started. The pound-nets have however produced a larger yield with regard to herring-fishing which much exceeds that known in the years around 1900. About 3000 men have been engaged for a number of years in the Limfjord-fisheries; the number of full time fishermen has been increased in the latter years, at the same time the number of part time fishermen has decreased, and a still more intense fishery will differentiate these proportions. At any rate a number of people living along the coasts of the Fjord, who have had good extra earnings from fishery will suffer by a more intense exploitation.

And what if the present high price of fish falls? Now, as always, I maintain, that the Limfjord fisheries are more suitable for small scale fishing than for the too expensive motor-fishing which does not increase the yield. There is no que-

stion here of herring-fishery or cod-fishery or of other migrating fish, these must be taken when they are to be had, and this is the case with the present development of fishing apparatus, but eel and plaice may be relied upon as stationary fish as long as they remain in the Limfjord, and they ought to be treated as such, i. e. protected suitably in order to give a big yearly yield.

I am not going further into the question of principle as to whether extensive exploitation or a continuation of the minor fisheries of former years is to be preferred; but if the extensive exploitation be chosen and the engine power extended, care must he taken that the extension is not carried on to such a degree as to decrease the yield in weight of eel and plaice. As regards the Limfjord we have restrictions for the size of mesh and a minimum size limit, which to a certain extent protect eel and plaice, for if these fish are caught just as they reach the size or just as they can escape through the mesh, the yield vill become even less than at present. We have, therefore, also a close season during some of the growth period of plaice, viz. spring, summer and part of autumn up to ab. 15' Nov. This period has by legislation been adapted to the old mode of fishing, plaice-fishing with the seine is thus permitted from 15' Sept. till 15' April; according to my opinion it would be absolutely destructive, if motor winches were to be introduced during the whole of this period, this should certainly not be permitted before 15' Nov. (alternatively 1' Nov.) and only till 1' April, the latter date as formerly.

Eel seine are only permitted during the summer (1st May—14th Oct.) and I must admit that whether they are hauled by hand- or motor-winches surely amounts to the same, but to give permission to lengthen the line from 75 m to 125 m would be of great danger to the stock of plaice, as it will then be possible to take plaice with nets made for catching eels, and this is bound to be detrimental to that fishery: I must absolutely recommend that this is not done. It has been stated that the question of the length of line may easily be got round by towing the seine along with the boat, but I wish to remark that one cannot with any advantage tow as far with short lines as with long; and even if permission be given for having long lines, the towing may as easily be carried on against the law as now is the case with short lines, so in this way the control over this illegality is in no way improved upon.

If there is no wish to keep to the old regulations regarding restricted machine exploitation, which I consider best for the fishermen of the Limfjord as a whole, I would advice a trial of some years of giving permission for the use of motor power for plaice-seine and cod-seine from 15' Nov. (eventually 1' Nov.) to 1' March, and for eel-seines with the present length of line (75 m) during the times fixed for this fishery; but no larger yield in weight is to be expected from this permission for more intense fishery, only heavier expenses and perhaps a smaller yield in weight.

It would be regrettable to call forth the same situation in the Limfjord as regards the plaice fishing, as is the case in most of our waters, where the intense

fishery has thinned out the stock to such an extent as to diminish the yield by weight year by year for a number of years, and where suitable legislation ought to restrict the exploitation, as has been done in the Limfjord where long experience has shown the great importance of protection.

Seine-net fishing as carried on in the Limfjord has, on the whole, its great advantages, when kept within proper bounds; for by this system, plaice below standard size can more easily be spared and thrown back living into the water; this is not the case with moored nets in which the caught plaice remain in the nets all night, often being killed by starfishes and gasteropods. If this night-fishery with nets were forbidden or even restricted on areas where plaice have been transplanted, there would surely be a larger yield from this transplanting than now is the case. On other places in the Limfjord where there is plaice fry in abundance this restriction would not be neccessary.

It has often been suggested that if the majority of fishermen cannot understand that protection is to their advantage, the best procedure is to teach them by abolishing protection. This line of argument has its points, but this method is expensive and will entail several disadvantages to the population, and it is a question whether the majority of fishermen will ever learn anything by this method, for they are a quickly changing population, constantly being renewed by young members. The one who has a better understanding of the importance of protection, can at any rate not agree to recommend such educational experiments regarding a matter of so vast importance to the nation, as long as there are other modes of procedure.

Postscript, not sent to the Ministry:

The statistics of the yield in weight of fisheries in the Limfjord during the 12 last years show the herring fisheries to have varied from abt. 800 tons to more than 4000 tons fluctuating largely from year to year; the cod-fisheries have varied from abt. 60 tons to more than 1000 tons; both these fisheries have accordingly varied considerably more than the eel- and plaice-fisheries, the reason being that the stock of cod and herring are very changeable in the Limfjord, while the stock of eel and plaice are far more stable.

Yield of eel- and flat-fish-fisheries in the Limfjord in kilo and Kroner during 1890—1923.

Year	Eel-fisheries		Flat-fish-fisheries	
	Kilo	Kroner	Kilo	Kroner
1890		356.031		252.665
1891		441.090		225.375
1892		462.481		300.870
1893		528.093		310.090
1894		549.859		319.950
1895		538.052		300.280
1896	710.578	501.712		228.557
1897	754.310	533.340		209.560
1898	677.360	472.630	1.062.300	277.590
1899	672.829	582.155		294.910
1900	753.365	642.129	1.355.355	310.650
1901	855.533	737.965	671.336	195.570
1902	642.368	527.680	1.227.150	331.770
1903	505.700	488.375	1.607.705	496.460
1904	667.996	604.955	1.145.888	354.155
1905	899.468	839.020	730.405	229.415
1906	922.042	855.416	482.020	218.680
1907	866.252	826.915	703.098	298.260
1908	843.331	813.320	947.322	421.710
1909	675.225	606.010	776.759	377.470
1910	908.323	876.708	864.185	409.600
1911	1.013.972	935.220	862.815	402.560
1912	1.270.340	1.188.595	734.220	358.730
1913	1.131.210	1.072.980	1.018.850	446.570
1914	1.244.925	1.140.590	1.371.430	488.550
1915	920.048	1.046.960	696.790	411.550
1916	689.390	1.574.755	663.570	668.440
1917	790.075	1.509.965	966.680	549.690
1918	593.635	1.627.760	543.650	362.755
1919	811.365	1.948.660	731.580	603.695
1920	853.355	2.181.030	528.110	538.140
1921	924.890	1.952.115	1.112.930	830.440
1922	1.066.280	1.613.870	1.235.720	656.055
1923	755.675	1.617.560	897.780	585.280

Continued Studies on the Quantity of Fish Food in the Sea Bottom.

By

H. BLEGVAD.

CONTENTS

		Page
Introduction		29
	First- and second-class fish-food	29
	Relation between the foods of young and adult fish	30
	The technics of valuation	30
I.	Proportion of edible and inedible animals in the different animal communities	31
	Macoma baltica community	31
	Abra community	34
	Venus community	35
	Echinocardium-Filiformis community	36
	Haploops community	37
	Brissopsis-Chiajei community	37
	Distribution of the fishes on the sea-bottom and their food	37
II.	Variations in the quantity of fish-food	39
	A. The Limfjord	39
	a. The most common fish-food animals: *Abra, Solen, Mya, Pectinaria, Corbula, Nucula*	41
	The Thisted broad	41
	The Livø broad	41
	Years of spat-fall in Thisted and Livø broads	43
	The Nissum broad	45
	Appearance of *Corbula gibba* in the Nissum Broad	45
	The small quantity of first class fish-food in the Nissum broad is especially due to the depredations of fish	45
	In other broads the disappearence of the „fish-food" animals cannot alone be due to the depredations of fish	47
	Difference in quantity of food in neighbouring broads of the Limfjord	48
	b. Other „fish-food" animals: Worms and small molluscs	48
	c. Gross amount of fish-food	49
	d. Quantity of fish-food and yield of fisheries	49
	B. The coast of Funen	52
	North of Funen	53
	Nyborg–Svendborg, *Abra* communities	54
	Assens–Faenø	54
	Nyborg–Svendborg, *Macoma* communities	54
	C. Other waters	55
	D. Resumé	55

SINCE Dr. C. G. Joh. Petersen in 1909 began the valuation of the Danish waters, a considerable amount of material relating to benthic animals has been collected by the Biological Station by means of a small bottom-sampler, capable of taking $^1/_{10}$ m^2 of the bottom. The main part of this material is kept at the laboratory of the Biological Station, so that it is possible to make comparisons between the size and age of the animals. The number of animals and their gross-weight is recorded on board, immediately after they are taken and have been noted on special lists. In order to get information as to which of the animals from the sea bottom serve as fish-food, a great number of stomachs of fish from the areas valued have been examined at the same time as the valuation has been carried on. It is thus possible to calculate the amount of fish-food present at a certain time and within the investigated area.

These examinations proved, that the bottom-sampler nearly always brought up the same animals of the bottom-fauna as were found in the stomachs of the fishes. It was however seldom that the same animals dominated by number and weight both in the contents of the bottom sampler and of the stomachs. This depends upon the fact, that the fishes make a selection of the existing bottom-fauna, and not only a selection among the different species but also among the different sizes of the same species. Accordingly I have divided the sea-bottom animals into two classes according to their value as fish-food.

The species of fish of the food of which this work treats, are our common food-fish living at the sea-bottom in the waters inside the Scaw, i. e. plaice, dab, long rough dab, flounder, eel, cod, whiting and haddock. Examination of the stomachs of these fish shows the *Polychaeta* and the *Crustacea* to be first class food for all these species of fish; next come the small Lamellibranchiata species: *Abra, Solen, Nucula, Tellina, Macoma baltica, Mactra subtruncata* and others, also the young *Mya, Mytilus, Cyprina, Scrobicularia* and *Macoma calcarea*. These are first class food for flat-fish, also for the eel and haddock. On the other hand the thick-shelled *Astarte*-species are not consumed, and only the very smallest specimens of the thick-shelled *Venus gallina:* neither the large *Mya* (eel and cod can however sometimes bite off siphons of large *Mya*), *Mytilus* and *Cyprina* or the thick-shelled gastropods *Turritella* and *Aporrhais. Buccinum* and *Nassa* are,

however, often eaten by different fish, e. g. cod and dab. The *Corbula* can only be counted as second class food, as it is evidently only eaten by the fish for want of anything else. Also the big *Macoma calcarea* and *Scrobicularia* are of little importance as fish-nutriment, for only the largest plaice can eat them. The Echinoderms come only secondarily, partly on account of their small nutritive value and partly because only few fishes eat them. *Asterias* and large *Echinidae* are never eaten by the fishes; a good deal of *Echinocyamus* and quite small *Echinocardium* and *Echinus miliaris* are however eaten, especially by *Gadidae; Amphiura* and *Ophiura* species are eaten by dabs, long rough dabs and sometimes by haddock; but plaice, flounder and eel hardly ever consume *Echinodermata* in our inner waters. Of *Actinia* the larger attached forms are only exceptionally found in cod and dab stomachs, the smaller free-living forms *(Edwardsia, Cerianthus)* have been found somewhat more often inside these same fish, but never in large quantities. Quite unimportant for the nutrition of fish are sponges, *Bryozoa* and *Hydrozoa.*

There is often a difference between the food of the young and the adult fish; when in their very smallest bottom stages the fish have a partiality for small worms and *Crustacea.* Of the *Mollusca* they only take the small thin-shelled individuals, or else they bite off and consume the thin siphons of such as the *Abra* or *Macoma* species. Especially in the stomach-contents of dabs of the Ogroup I have found such bitten-off pieces of siphons. Of the *Echinodermata* the fry only consume the very smallest specimens; the young dabs for instance select the quite small almost microscopic *Ophiura* which have just reached the bottom stage. As the fishes grow they take larger and larger specimens of their special food-species; thus the plaice take molluscs and worms of increasing size. The maximum size of Lamillebranchiata however, which can be consumed by plaice in our waters are about 3 cm long. By and by as the cod grow they start eating larger crustaceans and worms, such as crabs and large *Aphrodite* instead of small crustaceans and worms. The Echinoderms which are seldom consumed by individuals of the 0 group, are often largely eaten by the adult cod, especially where there are so-called „Rich-*Modiola*" communities in places with a rapid current. Here cod-stomachs are often found to be stuffed with large Echinoderms, such as *Ophiopholis, Psolus, Phyllophorus* and *Strongylocentrotus droebakiensis,* a diet one would believe to be of a somewhat poor and indigestible character. The very big cod are almost solely eaters of fish and large *Crustacea.* For further reference see my treatise on fish-food in Report of the Danish Biological Station, 24, II, 1916.

It is impossible to carry out a quantitative determination with sufficient accuracy as regards the number of sea-bottom animals within the *Zostera*-zone along our coasts by means of the 0,1 m^2 bottom-sampler, therefore only the bottom area outside the *Zostera*-zone has been considered here. Each valuation has as far as possible been kept within one certain community, and the number of bot-

tom-samples in each valuation has always been fixed with the object of getting a truly reliable picture of the quantitative and qualitative composition of the sea-bottom fauna. As a rule the procedure has been to mark off a number of stations on a chart within the area which was to be investigated, and which, according to previous experience, had proved to contain a fairly homogenous stock of sea-bottom animals. At each of these stations one or two samples were taken with „the bottom-sampler" the contents of which was immediately noted, each station separately (see for intance the lists from the Limfjord in Report of the Dan. Biol. St. 20, 1911). Immediately on the completion of the valuation, the total weight and number of each species was recorded on board the station's steamer „Japetus Steenstrup". For the sake of comparison both number and weight have later been calculated per 1 m^2 bottom surface.

I. Proportion of edible and inedible animals in the different animal communities.

To give an idea of the amount of sea-bottom animals in the different animal communities, I have in fig. 1 given a graphic representation comprising some characteristic examples of the quantities of the different class of animals, *Mollusca*, *Chaetopoda*, *Crustacea* and *Echinodermata* expressed in g rough weight per 1 m^2 of bottom surface. Above the thick line are introduced the edible animals, below the line the inedebible ones. For the sake of comparison the weight is shown in rectangles, 1 g equalling 3 mm^2 on the diagram. As it appeared that within each community there might be great difference between open waters on the one side and closed waters on the other, a type from each of the animal communities in question has been selected. As regards the *Venus* community of the Kattegat both spring and autumn samples are seen, to display the great difference. Regarding the extent of the communities in our waters see chart in Report of Biol. St. 25, 1918.

As a typical closed water within the *Macoma baltica* community the Roskilde Fjord has been chosen. It will be seen that here Lamellibranchiata constitute the entire bottom-fauna. Further, all these bivalves are of slow growth, rather thick-shelled, and may reach an age of several years viz the species *Macoma baltica*, *Mytilus edulis*, *Cardium edule* and *Mya arenaria;* as regards *Mya* and *Mytilus*, there are so many large specimens that I have estimatet about one half of the weight to be unsuitable for fish-food. Here it is however not easy to draw a line, possibly some of the largest eels in the fjord may be able to consume *Mya* above 3 cm, which size I have here put as the limit. But evidently there is an abundance of fish-food, more than 180 g pr m^2. This type consisting almost solely of bivalves several years old is found all over in our closed waters, but the quantities vary somewhat according to the localities. Thus the inmost part of Nyborg Fjord, at Holckenhavn, shows enourmous numbers of *Mytilus*,

but comparatively few other bivalves (see Report of Biol. St. 21, 1913, Appendix pg. 35 Stations 16 b and a). The same is the case in Bramsnaesvig (1. c. pg 58, St. 6); in the Sealand archipelago another large bivalve of several years old also appears in considerable numbers, this is the *Scrobicularia plana* (see also 1. c. page 56, St. 5). Where the bottom sampler has been used with success on *Zostera*-areas in our fjords, we partly find the same species of bivalves but in less quantity and together with smaller *Gastropoda, Rissoa, Littorina* and others, also *Crustacea* and different kinds of *Polychaeta* (see for instance the lists 1. c. pages 34—35, Stations 1 a, b, c, page 42 Station 8 a and b, page 54 St. 2, page 55, St. 4, page 56 St. 8, page 57 St. 4.) Inside the Zostera »*Macoma-baltica*« bivalves several years old are many and represented by large specimens and as a rule accompanied ay a number of *Arenicola marina* (see for instance 1. c. page 55, Station 3 a and b). But these animals in very shallow waters surely play a subordinate part as a fish-food, as few adult fish live in these waters. However the fry of the above mentioned bottom animals are important food for the fish-fry, for instance for young flounders and plaice, which principally live in the shallow water.

Common to all the samples from the *Macoma* communities is the small number or total absence of *Echinodermata*. In the inner fjords, as the Roskildefjord, they are totally missing, in the other fjords and inlets they are only represented by *Asterias rubens* (see for instance 1. c. page 58 St. 6) which being predatory animals, whose existence depends principally on the existing abundance of *Lamellibranchiata*, are only met with in small number, as a rule only a fraction of the number of bivalves.

The above is also the case with regard to the more open waters of the *Macoma* community. Typical is the Baltic (see fig. 1). Here it is at once evident how comparatively small is the available quantity of food; it consists mainly of the same bivalves as already mentioned, i. e. first of all the *Macoma baltica* together with the *Mytilus edulis, Cardium edule* and *Mya arenaria*, but now the *Polychaeta* often also play a role of importance to the fish. In the Baltic these are mostly represented by *Terebellides stroemi* (see 1. c. pages 48—50, Stations 2, 8, 9, 4 and 5); along the open coasts of the Sound and the Belts *Nephtys, Aricia armiger* and sometimes *Arenicola* (see 1. c. pages 34—35 Stations 1 and 16, pages 37—39 Stations 14, 29, 3, 10 and 30, pages 41—43, Stations 6 and 8). In the valuation shown in fig. 1 between the Kadet-channel and Hyllekrog, the large thick-shelled genera, *Astarte* and *Cyprina* (which rightly do not belong here in the *Macoma* community) form the greatest percentage by weight of the animals taken, but as already mentioned they are uneatable for the fishes. In the other Baltic sample it is mostly the large *Cardium edule* which constitutes that part of the sea-bottom stock of animals, which is valueless for fishes. The nutritious amount of fish-food in the open waters of the *Macoma* region seldom exceeds 20 g per m^2, and is often far below.

g. pr. m²
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
MYA ARENARIA
MYTILUS EDULIS
CARD
MAC. BALT
CARD. ED.
CYPRINA ISLANDICA
ASTARTE
MYA TRUNCATA AD.
CYPRINA
ECHINOCARDIUM CORDATUM
ABRA ALBA
SOL. PELL.
MYA TRUNCATA JUV
MAC. CALC.
OPH. ALB.
POLYCH.
HEPATUS
MACTRA SUBTR. JUV
PECT. NOR.
ECHIN. CORD.
MACTRA
AMPH. FIL.
POLYCH.
AMPHIURA FILIFORMIS
9
HAPLOOPS
PECTEN
STR. GROEN.
MODL.
BALTH. PRICH.
AMP. CH.
BALTH. SYR.
Roskilde Fjord 8-7-1923
Gedser-Grønsund 16-4-1921
Kadetrenden-Hyllekrog 17-5-1922
Thisted Bredning 7-10-1917
Nord for Fyen 8-9-1921
Kattegat (Aalborgbugt) 29-6-1923
Kattegat (Aalborgbugt) 7-9-1922
Nordsøen Nr 1 13-7-1911 32 m.
Nordsøen Nr 10 5-10-1911 8 m
Sejerø-Slettehage 30-5-1922
Frederikshavn-Skagen 24-6-1921
W.S.W. f. Kullen 4-6-1912
Ø.f. Anholt 24-7-1922
g. pr. m²
Community:
Macoma
Abra
Venus
E.-Fil.
Ha.
B.Ch.
Mollusca
Echinodermata
Polychæta
Crustacea

Fig. 1.

If we however consider the *Abra* community from which we see two samples in fig. 1, we find quite another type of abundance. Here the main part of the fish-food is also bivalves, but unlike the *Macoma* community it is here the quickly-growing, thin-shelled small bivalves: *Abra alba, Solen pellucidus, Macoma calcarea* and young *Mya truncata.* The *Polychaeta* now become an essential part of the amount of food, 10—15 g per m^2; the principal species are *Nephtys (ciliata* and *hombergi)* and *Pectinaria koreni.* As regards the *Echinodermata* there is a pronounced difference between the open and more closed water. Typical for the latter is the Thisted broad. The *Echinodermata,* represented here by two species, *Ophiura texturata* and *Asterias rubens,* only form a small percentage of the actual weight of the total stock, and here they are of no importance as fish-food. In the more open waters, however, for instance the extensive *Abra* area north of Funen, the large heart-urchin, *Echinocardium cordatum,* composes almost one half of the weight of the existing amount of animals. In these waters the *Ophiurae* are eaten by such fish as dab and long rough dab and accordingly they are counted among the fish-food; here it is however not *Ophiura texturata,* but *Ophiura albida,* which is dominant. *Abra alba* alone constitutes more than half of the available amount of food. This important fish-food is eagerly sought after, especially by the flat-fishes, and it is therefore evident, that the areas with abundant *Abra* are specially suitable feeding-places for plaice. Such we find for instance in the Samsø Belt (see Report B. S. 21, 1913, Appendix, pages 17—20, Stations 3, 4, 15, 25, 26, 27 a and b) and in the Great Belt (l. c. page 34 St. 28) on the soft bottom mixed with clay. In the current-channels, or where from other reasons the bottom is more hard, the fauna becomes scarce of *Abra* and sometimes a number of the species *Astarte,* valueless to the fish, appear here in great quantities (for instance the Great Belt, 1. c. pg. 25—31, Stations 2, 22, 24 and 11, 13, 15, 25, 6 and in the Little Belt 1. c. pgs. 40—41, Stations 1 and 9). *Macoma calcarea* is everywhere an important — and weighty — constituent of the fish-food. In the Little Belt and in the southern part of the Great Belt and the Sound where the fresh water of the Baltic is felt the heart urchins are not found and the fauna is poorer (however never as poor as in the open water of the Macoma-community) but the *Macoma calcarea* is always a very characteristic animal and found in great numbers. The big broad of the Isefjord agrees, as a less open water, quite with the Limfjord; we find neither *Macoma calcarea* nor *Echinocardium cordatum.* The fauna is caracterised by small bivalves as *Solen pellucidus* and *Corbula gibba,* that are sometimes found in great numbers; in the same way *Pectinaria koreni* may in certain years be very numerous; on the other hand *Abra alba* is curiously enough, as a rule, but sparsely represented.

The *Abra* community on a whole, therefore, offers good conditions for the fish: many small quick-growing bivalves and a fair amount of worms, all first class fish-food .The *Echinodermata* consist partly of two *Ophiura*-species, consumed by certain fish, partly of the non-destructive detritus-consuming heart urchins; *Asterias*

rubens is seen now and again, but very scattered. At the so-called „Rich *Modiola*-stations", places with rapid currents in the Samsoe Belt, Great Belt and the north part of the Sound and with numerous species of animals, mostly belonging to the so-called „Epi-Fauna" (see Appendix in Rep. B. S. 21, 1913, pgs. 15—17, Stations 21, 22, 23, 5, 6, 9 and 10 and pgs. 25—26, Stations 2, 22 and 24, and pg. 51, Stations 1 and 4) — the *Echinodermata* are abundantly represented by large numbers of *Ophiopholis aculeata*, *Psolus phantapus* and *Phyllophorus pellucidus*, all eaten by cod-fish; but these *Echinodermata* can only, as mentioned above, be considered second class fish-food. Of the *Crustacea* the *Amphipoda* (among which the different species of the genus *Ampelisca* are the most frequent), the Pagurids and the *Diastylis rathkei* are sought after by the fish, but nowhere are they found in quantities per m^2 in any way comparable to the molluscs, worms or *Echinodermata*. Open waters are generally far poorer as regards fish-food than the more closed waters which at special times of the year are very abundant with small bivalves.

On examinating the *Venus* community, a glance at fig. 1 will immediately make evident the large difference of the food quantities at the different seasons, the reason being principally the great increase of young *Mactra subtruncata* which takes place during the summer. To represent open waters 2 samples have been chosen from the North Sea. Althoug the Danish Biol. St. has not taken many samples there, it may be looked upon as fixed that this water as a whole is comparatively poor in comparison with more closed waters. The quantity of food in the first mentioned sample (North Sea, Station 1. See Rep. B. S. 21, 1913 Appendix pg. 63) of 13' July is only about 8 g per m^2 and partly consists of small molluscs and worms, partly of *Ophiura*, *Echinocyamus*, *Amphioxus* and *Amphipods* in small quantities. The weight of non-edible animals amounts to about the same; these consist of large molluscs as the *Cyprina* and large *Echinodermata* as *Asterias*, *Spatangus* and *Astropecten*. But the second sample taken on 5' Oct. (North Sea, Station 10. See Rep. B. S. 21, 1913, appendix page 66) contains more than 16 g of fish-food per m^2, of which the young *Mactra subtruncata* compose 14,7 g. Below the line is entered 4, 9 g adult *Mactra subtruncata* which on account of their size and thick shells must be considered as unfit for fish-food. In the recent British investigations (Davis: Quantitive Studies on the Fauna of the Sea Bottom. No 1. Fishery investigations. Series II, Vol. VI No 2, 1923) the same observations as to a sudden appearance of huge numbers of young *Mactra* in some years are made out regarding the Dogger Bank. There is no doubt that the young *Mactra subtruncata* play an enormous part as fish-food in large parts of the *Venus* communities of the North Sea.

Comparing the Kattegat with the North Sea the former must be considered as a more closed water. The quantity of animals is considerably larger here, as seen by the two examples given in fig. 1, which are taken from the same locality viz. the bay of Aalborg, but in June and September respectively. The first of the

samples shows a small quantity of food, barely 13 g per m², consisting of small molluscs, *Polychaeta*, *Crustacea* and *Ophiura*, but there is a considerable amount of *Echinocardium* (more than 100 g per m²) which together with *Venus gallina* compose the main part of the animals useless as fish-food. In the second sample however the food-amount per m² has increased to 85 g of which about $^2/_3$ consists of quite young *Mactra subtruncata* born the same year. The great majority of these *Mactra* disappear — in contradistinction to the condition mentioned in the North Sea — during the winter; in spring time their dead shells are found by the million on the sea bottom. A vast quantity of these animals is consumed, partly by fish (especially plaice) partly by *Echinodermata* and other predatory animals (see Rep. B. S. 21, 1913, pg. 30). Persecution from other animals is however not enough cause to explain the total disappearance of these *Mactra*. The fact is that early in the spring a large number of *Mactra* shells are found tightly closed, but containing a decayed pulpy substance. The animal itself has consequently not been eaten, but must have perished through some physical reason, perhaps cold. — We also see young *Pectinaria koreni* flourish, and they are first class fish-food; these *Venus*-areas in the Kattegat are therefore much sought — for feeding places in the late summer for many kinds of fish, especially flat-fish. As the bottom sampler often cannot get up the animals which dig deepest down in the hard bottom of the *Venus* communities, it proves impossible to state the approximate quantity of the *Arenicola marina*. Now and again it forms part of the stomach-contents of flat-fish in these communities.

On the whole it may be stated that as a rule the *Venus*-communities offer comparatively small quantities of fish-food, often less than 10 g per m²; the more closed waters are, however, as was the case with the previously mentioned community, more plentiful than the open waters. In a number of places, especially in comparatively shallow waters, the autumn brings an abundance of *Mactra subtruncata* (at times also *Pectinaria*) and consequently the quantity of food increases considerably for a short time; but in the Kattegat nearly all these animals disappear before the following spring.

On areas of the Kattegat where *Echinocardium cordatum* and *Amphiura filiformis* predominate in the so-called *Echinocardium-Filiformis (E. Fil)* community, we meet a huge number of *Echinodermata* (see fig. 1). First of all naturally the characteristic animal *Amphiura filiformis*, which is entered as a food-animal, and besides the *Echinocardium cordatum* which composes the main part of the animals inedible for the fish. The rest of the food-animals are mostly different kinds of worms, small *Mollusca* and *Crustacea*; the large *Gastropoda Turritella terebra* and *Aporrhaïs pes pelecani*, when adults, are quite inedible to the fish and have accordingly been entered below the line. Of the two examples from this community put down in Fig. 1, the first is from the South part of the Kattegat (Sejerø-Sletterhage) the other from the Northern part of the Kattegat (Frederikshavn-Skagen). It is noticeable that the quantity of *Echinodermata* is somewhat larger in

the latter sample; of other animals the weight is, however, equal per m^2. Other samples from this community may be found in Rep. B. S. 21, 1923, Appendix pgs. 5—6, Stations 14, 46, 41, 11, 31.

In the »*Haploops*« (Ha) community, which only covers a limited area of the eastern Kattegat, we meet for the first time a community where the *Crustacea* are able to hold their own in quantity against the other classes of animals. As will be noticed from the sample shown in fig. 1, the small Amphipod *Haploops tubicola* constitute no less than 30 g per m^2; the remaining food consists mostly of *Polychaeta* especially the large characteristic forms *Aphrodite aculeata* and *Eumenia crassa*; though less in number there is also a quantity of eatable Molluscs and *Ophiura*; some few Nemerteans and the crab *Hyas coarctatus*, much sought after especially by cod, form the remainder of the fishes diet. Inedible animals are only a few large bivalves, *Venus ovata* and *Pecten septemradiatus*, also the sea urchin *Strongylocentrotus droebakiensis*; but from the sample in Rep. B. S. 21, 1913, Appendix page 4 Stations 6 and 7, it appears that in this community also may be found a large number of heart-urchins (*Brissopsis lyrifera*) and some *Amphiura*.

In the deep eastern part of the Kattegat *Echinocardium cordatum* is replaced by *Brissopsis lyrifera*, and *Amphiura filiformis* by *Amphiura Chiajei*, but otherwise conditions in the *Brissopsis-Chiajei (B. Ch.)* community do not differ greatly from those of the *E. Fil.* community. In both places the large numbers of *Echinodermata* are of great importance, represented by the edible *Amphiura* and the inedible sea-urchins. Sometimes the *Polychaeta* here form a considerable part of the fish-food on account of the frequent appearance of the large form *Eumenia crassa*. The sample shown in fig. 1 was taken East of Anholt; other samples from this community are to be found in Rep. B. S. 21, 1913, Appendix pgs. 1—4 Stations 20, 10, 25, 5, 19, 16, 42, 24, 4.

I will not here give further details of the communities living in still deeper water, the *Brissopsis-Sarsi* community and the *Amphilepis-Pecten* community in the Skagerak. The *Brissopsis-Sarsi* community often contains considerable numbers of the small bivalves *Abra nitida* and *Axinus flexuosus*, against which the *Amphilepis-Pecten* community no doubt always is poorly off from a quantitative point of view.

With regard to the fish living at the sea-bottom on these areas, Dr. Petersen has proved in Report B. S. 25, 1918, pg. 44 ff. that the *Macoma, Abra, Venus* and *Echinocardium-Filiformis* communities in the open waters from the Baltic into the Kattegat may be described as the dab-area, dab, plaice and flounders being the most frequent fish. According to the stomach examinations made by the author, the main diet of these fish in these communities (see Rep. B. S. 24, 1916. pgs. 58—59) consists of small bivalves and worms. Also dabs and flounders con-

sume a good deal of *Crustacea*, and the dab in addition many *Echinodermata* especially *Ophiura*. Cod, whiting, brill and turbot which are frequent in this dab-area are fish-and *Crustacea*-eaters, the cod besides often takes *Echinodermata* (1. c. pgs. 57, 62 and 65). In the closed waters in the *Macoma*- and *Abra*-communities the eel is an important food-fish. Its main food ordinarily consists of Crustacea, also worms and molluscs; but it is a characteristic feature that this order is reversed in the Limfjord and the Isefjord with their large quantities of bivalves; here the principal food is bivalves and *Polychaeta* (1. c. pg. 60). The same is the case with the cod in the Limfjord, though in other places it seldom eats bivalves.

The deeper living communities in the Kattegat, the *Brissopsis-Chiajei* and the *Brissopsis-Sarsi*, Dr. Petersen characterises as the haddock-area. This fish is with us and in these areas mainly an eater of *Echinodermata* and *Crustacea* (1. c. pg. 63); it is accompanied by whiting, dab and long-rough-dab. All these fish here eat *Echinodermata*, *Crustacea* and *Polychaeta* especially *Eumenia crassa* and *Aphrodite*. Among the *Echinodermata* the *Amphiura*- and *Ophiura*-species are the chief food; peculiarly enough the fish often only seem to consume the very point of the arms of the *Amphiura*, and in several cases I have only found these in the stomach-contents and often in large numbers; it seems that the discoid bodies of the *Amphiura* are so deeply burrowed that they are difficult to get up, therefore the fishes content themselves by biting off the tips of the arms protruding from the bottom; this fact explains the many regenerated arm tips always found on *Amphiura*.

In the restricted areas of the *Haploops*-communities, whiting, cod and dab are the most frequent useful fish; while the cod mostly take worms as for instance *Aphrodite*, and large crustaceans such as the *Hyas* and *Crangon*, the whitings and dabs are here almost exclusively *Haploops*-eaters.

The above resumé shows that in the communities where the *Lamellibranchiata* are frequent, i. e. the *Macoma*-, *Abra*- and, at certain seasons, the *Venus*-communities, they become the favorite food of the fishes living in these communities; when the *Lamellibranchiata* become scarce, as in the deeper communities, we meet other species of fish not feeding on *Lamellibranchiata*. But in all communities are to be found two classes of animals, especially persecuted by the fish, i. e. the *Crustacea* and the *Polychaeta*. The only kind of our flat-fish not a *Crustacea*-eater is the plaice, and even this fish eats these animals in localities where there are plenty of *Ampelisca laevigata*, as for instance at the mouth of the Isefjord, and on certain places in the Aalborg bay. It is therefore peculiar that the *Crustacea*, as remarked already, are the quantatively poorest represented class of animals in all the communities, excepting the small limited *Haploops* community. It is very doubtful if it is the persecution of the fishes that keeps their numbers so small; it may be possible that this partly applies to large species of the higher crustaceans, but as regards the others, the *Amphipoda*, *Isopoda* and *Cumacea* it does

not hold good, how would it then be possible for a community like the *Haploops*-community to exist? There the bottom is quite covered by *Amphipod*-tubes close to one other; to the extent of many square kilometers there are here an average of 2—3000 *Haploops tubicola* on each square meter bottom area; again these small crustaceans have an extraordinary power of reproduction, though their life is very short (see Rep. B. S. 28, 1922). On the whole there can surely be no question of the fishes in our open waters having any special influence on the character of the sea-bottom fauna, our stock of fish has been too heavily diminished for this by excessive fishery; even the small *Mactra subtruncata*, which each autumn grow up in the *Venus* community of the Kattegat and are consumed by nearly all the fishes in incredible quantities, do not as mentioned above owe their total disappearance during the winter to the fish. Conditions change in more closed waters as for-instance the Limfjord, here the consumption of the fish often has shown its influence on the amount of fish-food.

Also the *Polychaeta* are everywhere in all communities a much sought-for diet. Their number is however often, unlike the crustaceans, comparatively large. Hardly anything is known of their length of life and ability of reproduction.

The considerable amount of small bivalves often found in the *Abra* communities plays a very important part for the fishes of the dab-area; and it is here the commonest animals which are a very sought-for and also a very nutricious fish-food. In the *Amphiura*-communities, where the commonest animals the two *Amphiura*-species also are consumed to a great extent, conditions are not so favourable, because these animals have so little nutritive value, especially so when only the arm-tips are eaten. There can therefore be little doubt that of all our sea-bottom communities the *Abra* community is able to feed comparatively most fish; here are, particularly in the more closed waters, a large number of nutritive and quickly-growing small bivalves; besides there are not a few *Polychaeta*, some *Amphipoda* and *Crustacea*, all first-class fish-food. The quantity of these animals varies however very much from year to year and from spring to autumn. These circumstances will be dealt with in the following section.

II. Variations in the quantity of fish-food.

Many of the valuations, untertaken over a number of years, have been repeated at different times of the year, but only those round Funen and in the Limfjord have been repeated systematically each year, as a rule at least twice a year, spring and autumn. Valuations in the Limfjord during the years 1909—17 have been treated by P. Boysen-Jensen in Rep. B. S. 26, 1919.

The result of this work shows that great variations take place from one year to another, both as regards quantity and species of bottom animals, and that the reason for these variations are: 1) of most of the animals, serving as fish-food, the

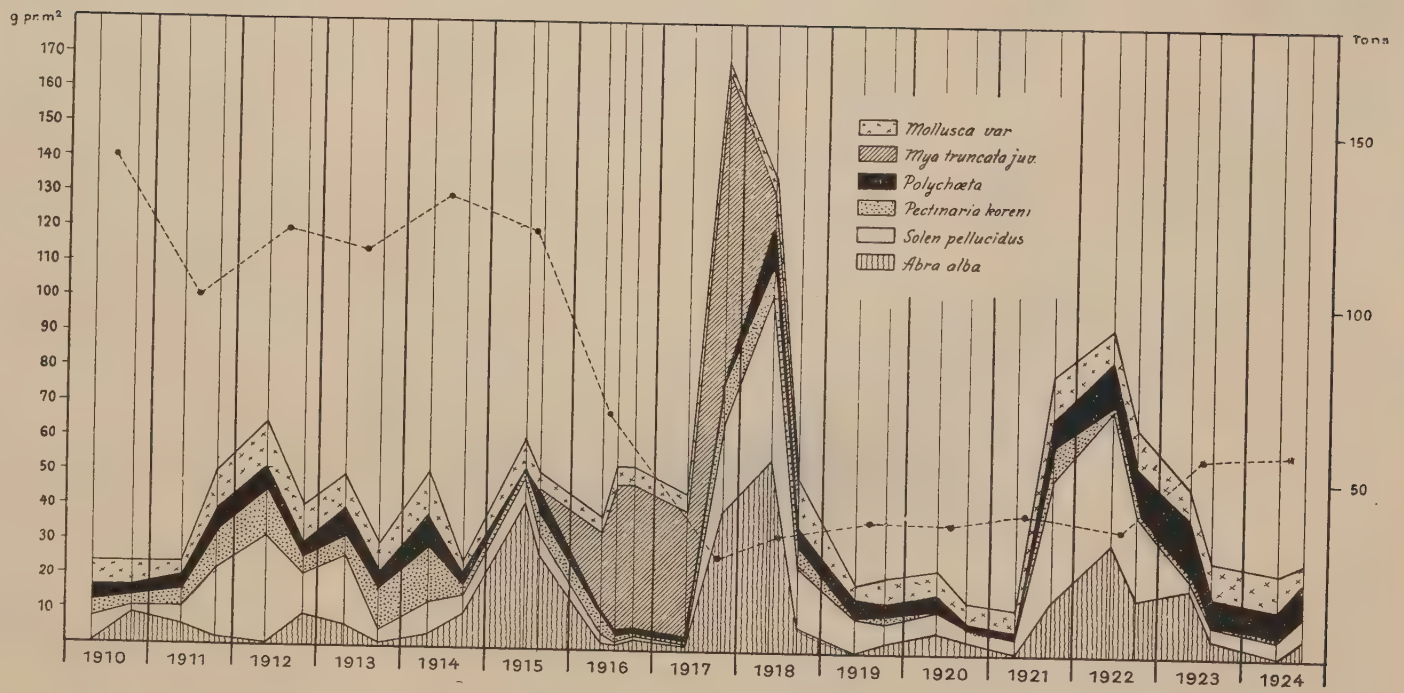

Fig. 2.

Quantity of fish-food in g (rough weight) per 1 m² in the Thisted broad during the years 1910—1924.

----•----•---- Yield of plaice fishery in tons in the Thisted and Visby broad during the years 1910—1924.

brood is not developed each year in greater amount, 2) the food-animals are quickly consumed and 3) the different species of bottom animals breed i. e. have a big spat-fall in different years (page 42). In the tables connected with this paper, Boysen-Jensen has entered number and weight of the common sea-bottom animals in the different broads of the Limfjord during the years 1909—17 and accompanying it a chart of the stations.

In order to render the general survey of these varying food-quantities more intellegible, I have reproduced them by curves, employing the procedure of laying down the quantities of food-animals per 1 m² as ordinates, and the times at which these quantities have been found as abscissae. According to whether 2 or 3 valuations have been made during the year, the food-quantity therefore has been marked 2 or 3 times respectively within each year at the place on the abscissa axis decided by the season. Only those species of food-animals which are of any quantitative importance have been marked separately, whereas the others have been collected in 2 groups, comprising *Polychatca* and *Mollusca* respectively. *Crustacea* are represented both in the Limfjord and round Funen by such a minimal weight-figure that from pratical reasons it has not been possible to show them in the figures.

Though the bottom-animals in the western broads of the Limfjord all belong to the *Abra* community, the following three associations, as also pointed out by Boysen-Jensen (1. c. pg. 33), may easily be discerned: 1) An *Abra-Solen-Mya* association, 2) An *Abra-Solen* association, and 3) a *Nucula-Corbula* association. Most typical representatives of these associations are the Thisted, Livø and Nissum broads respectively; for this reason I have chosen just these 3 broads to illustrate the variations in the Limfjord.

The curves for the Thisted broad*) (Fig. 2) show that it is mainly *Abra alba* and *Solen pellucidus* which produce variations in the food quantity of this broad; only during 1916 and 1917 the young *Mya truncata* play an important part; I may however remark, that these young *Mya*, appearing in the summer of 1915, were only found in the western part of the broad, and consequently has not been of any importance to the entire stock of fish in the broad. Where great quantities of *Abra* and *Solen* appear simultaneously we get the summit of the curve, viz. autum 1917-spring 1918 and autumn 1921-spring 1922. Poorest were the years 1916, apart from the local *Mya*, and 1919—20, i. e. the years immediately preceeding the best years. Medium good were the years 1911—15, in which the 3 important food-animals *Abra alba*, *Solen pellucidus* and *Pectinaria koreni* were present rather abundantly; but even during these years the quantity of food varies considerably from spring to autum.

Similar large variations are found in the adjacent Livø broad (fig. 3) which

*) The valuations of 1910—11 comprise 100 samples, 1912—17 50 samples covering 0,1 m² each, except the autum 1915 when only 10 samples were taken. From 1918 each valuation is based on 40 samples of 0.1 m².

as already mentioned is an *Abra-Solen*-broad*); the presence of an amount of *Corbula* may, however, be noticed from the diagram; but as only a very small percentage of this bivalve is consumed by the fish, and as it only appears locally, i. e. exclusively in the south-western part of this broad, it is but of small importance compared with the other food-animals.

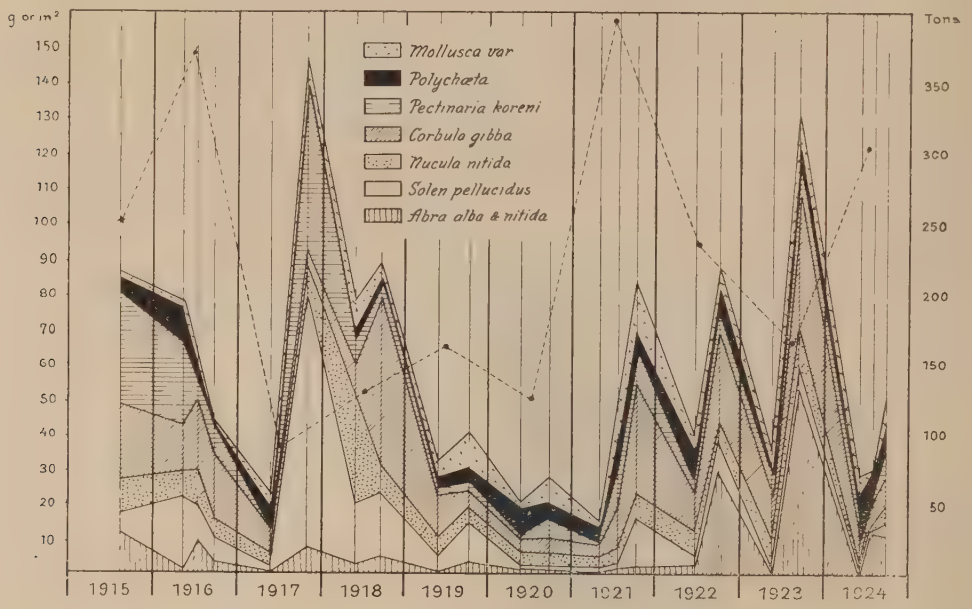

Fig. 3.

Quatity of fish-food in g (rough weight) per 1 m² bottom surface in the Livø broad during the years 1915–24.

---•------• Yield of flat-fish fishery in tons in the Livø broad during the years 1915–24.

The largest quantity of food was found in the autumn 1917, the same as was the case in the Thisted broad, and 1920 was in both places the poorest of all the years; on all other points the variations in the two broads do however not at all agree. A prominent feature is the fact, that while the food-quantity in the Thisted broad is stable or even decreasing from spring to autumn, it is as a rule largely increasing from spring to autumn in the Livø broad. Only the great *Solen*-brood-years**) in the Thisted broad 1911, 1917 and 1921 are able to raise the curve from spring to autumn, the brood appearing during the summer***). The

*) Valuation consisting of 22 samples covering 0,1 m² each in 1915—16, 10 samples in 1917, 25 in the remaining years excepting Sept. 1918 (14 samples) and July 1924 (10 samples).

**) By brood-years I mean years in which an abundance of brood appears at the sea-bottom.

***) It must however be noted, that in 1915 the first valuation was exceptionally made so late in the year, 22. June, that the abundant *Abra* brood for that year had already appeared; a spring valuation would probably have given a much poorer quantity of food.

fact of autumn valuations giving a lesser quantity of food than the spring-valuations is rather exceptional and is only met with in isolated cases. especially in poor brood-years. An obvious explanation of these circumstances is as follows.

It is well known, that a considerable number of plaice are transplanted into Thisted broad every spring; they are protected by law to a certain extent all through the summer, and then, as regards the majority, caught again during the autum. While, therefore, a considerable amount of food is being consumed by the many plaice during summer, winter time gives the food-animals a comparatively protected season as the greater part of the plaice have been fished up; therefore the stock of food-animals increases in weight during the winther (though the number decreases somewhat), consequently the spring valuations show a larger amount of food than the previous autumn valuations; and if a special good brood-year does not follow, the eager persecution by plaice, eel, cod and other animals will seriously impair the amount of food-animals, so that even the new brood cannot increase the weight per m^2 from spring to summer. In the other broads where there is a considerable stock of plaice all the year round, the consumption from autumn till the following spring will accordingly be comparatively large*) and this will decrease the stock, which during the winter gets no accessional brood. Doubtless a contributing cause is also the fact that good brood-years as regards *Abra*, *Solen* and *Pectinaria* are more rare in the Thisted broad than in the Livø broad. During the time 1915—24 only the years 1915, 17, 21 and 24 were good brood-years for *Abra* in the Thisted broad while, during the same time, there were double as many good brood-years for *Abra* in the Livø broad, i. e. 1915, 16, 17, 18, 19, 22, 23 and 24. For *Solen* only the years 1917, 18, 19, 21 and 23 were good in the Thisted broad, while 1916, 17, 18, 19, 21, 22, 23 and 24 all were brood-years for *Solen* in the Livø broad. For *Pectinaria koreni* the broad-years in the Thisted and Livø broads respectively were 1917, 21, and 1915, 17, 21, 22.

The curves in the figures 2 and 3 clearly show, what has already been emphazised by Boysen-Jensen, that the *Abra* (both *Abra alba* and the somewhat more rare *Abra nitida*) only live a quite short time in the broads of the Limfjord; as a rule they disappear in their second summer. The same applies to *Pectinaria koreni*, whereas *Solen pellucidus* often assert themselves even in the second and third summers; thus the Thisted broad in 1913, 1919 and 1923 still contained considerable remainders from 1911, 1917 and 1921 respectively. Boysen-Jensen unhesitatingly declares that the reason for the early disappearance of these animals is that they are consumed. This is hardly quite correct, and I will return to this question when treating the Nissum broad (pg. 47).

Boysen-Jensen has pointed out (1. c. pg. 23) the considerable difference in

*) It must be taken into consideration that the autumn samples as a rule have been taken in September, the spring samples in the month of May, so that even if the fish eat comparatively little in the real winter, there is all the same a great consumption during October, November, March, April and May.

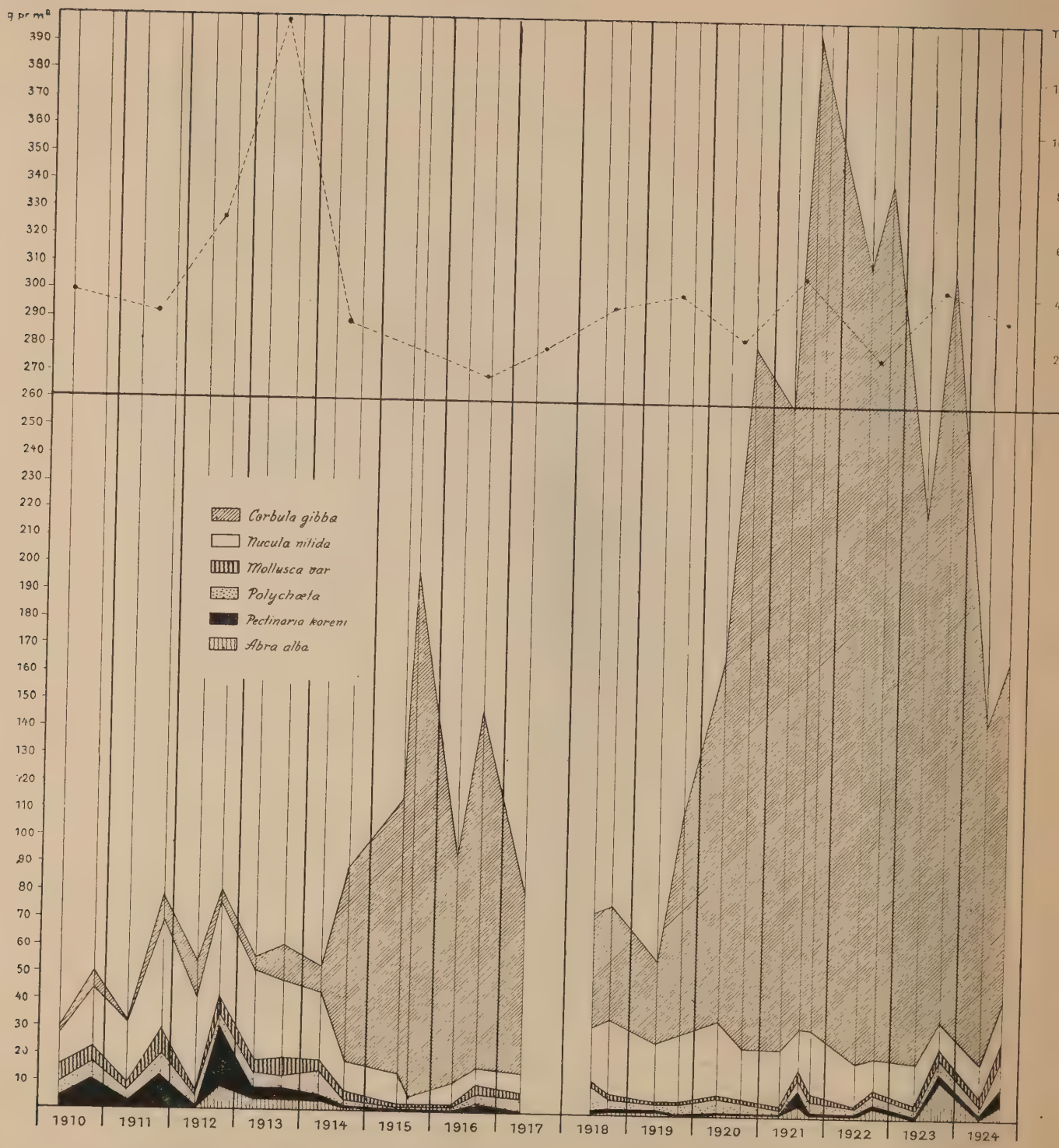

Fig. 4.

Quantity of fish-food in g (rough weight) per 1 m² bottom surface in the Nissum broad during the years 1910–1924.

·····•····· Yield of flat-fish fishery in tons in the Nissum broad during the years 1910–24.

the fauna inside and outside the 6 m line in the valuations of 1910—17 in the Nissum broad; he has, therefore, from the special lists of stations in the spring valuations calculated the weight of the food-animal in the two areas during the years up to 1917. I have now made the same calculations for the autumn valuations 1910—17; after 1917 the two areas have always been kept apart at the valuations, so that the deeper eastern part of the broad (outside the 6 m line) has been regularly valued by 30 samples of 0,1 m^2 each against the lower western part (inside the 6 m line) with 10 samples of 0,1 m^2 each. Variations of the quantity of food in the eastern part of the broads are shown in fig. 4, the figures being based on 30 samples of 0,1 m^2 each from 1918, previously on 33 samples of 0,1 m^2 each. The curves for the western part of the broad have not been reproduced here, as they offer less interest partly because the number of samples is too small partly because the variations here on the whole follow the variations in the eastern part; only the number of *Nucula* and *Abra* pr. m^2 is as a rule larger in the western part (1923 being an exception). *Pectinaria* and *Corbula* are, on the other hand, poorly represented in this part of the broad.

Fig. 4 gives a clear idea of the Nissum broad as a pronounced *Nucula-Corbula* water; during the years previous to 1914 *Nucula nitida* was the prevailing bivalve, but after this period *Corbula gibba* predominates, and simultaneously the quantity of *Nucula* decreases. The curve for *Corbula* has two pronunced summits, viz. 1915 and 1921; examination of the animals shows this being the consequence of the years 1913 and 1918 being especially good brood-years for *Corbula* in the entire western part of the Limfjord; the animals born in these two years may be sorted out by means of the growth rings in the shells and are seen to be prevailing in the following 5—6 years, culminating in 1915 and 1921 respectively. The latter year shows an imposing density of 3328 *Corbula* (weight 360 g) on an average per 1 m^2, which means less than 2 cm distance between the *Corbulas* all over the broad, as each of them only have had 3 cm^2 at their disposal. Unfortunately these animals, as previously mentioned, are not good fish-food, only the very youngest specimens being consumed by flat-fish. Neither are the *Nucula* in great demand by the fish, probably for the same reason as with the *Corbula* on account of the hard shell. The apparent large quantity of fish-food in the Nissum broad is therefore comparatively of little value; what there is of good food animals is minimal. Only in the years 1910—12 there was a good deal of *Pectinaria*, in 1912, 21, 23 and 24 a little *Abra*, but what may appear of these animals during summer has mostly disappeared before the following spring. This is not astonishing, considering the pronounced overcrowding of small plaice in the Nissum Broad, their growth being poor on account of the small quantity of food for them (see C. G. Joh. Petersen in Rep. B. S. 29, 1922, pg. 39). There can be no doubt that this overcrowding of plaice is the cause of the small quantity of the valuable nutritious animals *Abra*, *Solen* and *Pectinaria* in the Nissum broad; a further proof of how much sought-after the food-animals are here is that of all

the above mentioned animals only quite small specimens exist, the plaice evidently eating the larger inviduals as they grow up.

As an example of this is shown below the size and weight in April 1914 of *Solen pellucidus*, born in the summer 1913, from the broads of Nissum and Thisted respectively. It will be seen, that the average size of *Solen pellucidus* in the Thisted broad is nearly double of the average size of the same years *Solen* in the Nissum broad, while the weight of the same number of animals is more than five times as high in the Thisted as in the Nissum broad.

Nissum broad 18. and 20. April 1914		Thisted broad 23. April 1914	
mm	Number of specimens	mm	Number of specimens
6	5		
7	11		
8	16		
9	17		
10	12		
11	6	11	1
12	5	12	1
13	1	13	1
14	1	14	1
15	2	15	5
16	2	16	4
17	1	17	5
18	1	18	11
19	1	19	14
20	1	20	22
		21	13
		22	4
	82 specimens		82 specimens
Average size: 9,72 mm weight: 3,4 g		Average size: 18,77 mm weight: 17,1 g	

There is a fact which shows that it is not any physical condition which hampers the growth of the animals more in the Nissum than in the Thisted broad, and that is that now and again quite large specimens may be found in the former place, both of *Abra* and *Solen*; these must have evaded the persecution of their enemies accidentally; besides in the good brood years inviduals of the O-group, just after their appearance in about Aug.—Sept., i. e. before the carnivores have had a chance to devour large quantities of them, are quite as large in the Nissum broad as the corresponding individuals in the other Limfjord-broads; it is only

in the succeeding spring that the size of the individuals is influenced to a large extent by the depredations of the carnivores.

On the other hand, it must be noted that the fish (and, in addition, the carnivores among the lower animals) are not able to eat up quite the total of the existing quantity of food, always something remains; at the spring-valuations insignificant amounts of *Abra* left over from the previous summer have appeared. I, therefore, consider Dr. Boysen-Jensen to be wrong in maintaining that the carnivores alone (among which the fish doubtless are the largest consumers) are the cause of the early disappearance of the food-animals in the entire Limfjord; for when in the Nissum broad, where there is a surplus of famished plaice, everything is not eaten up, it is so much the more incredible that a plentiful stock of food-animals should be entirely consumed during winter in the Livø and Thisted broads, where there is a want of plaice (C. G. Joh. Petersen 1. c. pg. 39), this having been the case repeatedly with the *Abra alba*. Thus in the Thisted broad was not found one single *Abra* at the spring valuation in 1910, 1917 and 1919 and the same was the case in the Livø broad in spring 1917 and spring 1923, though the stock of *Abra* there in the summer 1916 was 151 specimens per m^2 and in the summer 1922 even 469 specimens per m^2. Among other points contradicting Boysen-Jensen's opinion the following are remarkable 1) Though *Solen pellucidus* is at least as much sought after by fish and other carnivores as *Abra alba*, it always has a comparatively longer life-time than the latter; in the Thisted broad life-time of *Abra* as a rule is only one year, that of the *Solen*, however, often more than two years. 2) The enormous amount of dead *Abra* and *Solen*-shells at the bottom of the inner Limfjord-broads cannot originate from animals consumed by fish (and probably neither by other carnivores) as they are perfectly whole and very often still connected by the hinge; on the whole they do not bear any trace of having been molested by other animals.

What other reasons can there be for the death of these animals? First of all there are in this connection the frosty winters, which evidently cause numerous victims for instance among the oysters. Reduction of the quantity of sea-bottom animals is therefore as a rule specially heavy in winter-time, and the spring valuations often show large quantities of decayed *Corbula* between their tightly-closed, strong shells, quite a similar case to that of the death in mass of the *Mactra subtruncata* in the Kattegat, previously related. The fact that *Abra* and *Solen* are not found in this condition, may depend upon the fact that they cannot close their shells so tightly and their soft parts therefore disappear quicker in decayed condition or are eaten by other animals. Even in the Nissum broad are found, besides a number of *Corbula*-shells, a great number of empty *Abra* and *Solen* shells in spite of the larger persecution of these species by fish, but not nearly as many as in the inner broads. Another conceivable cause of death might be suffocation from super-incumbent dead sea-weed. So little is, however, as yet known of such conditions that one must be content with mere suppositions.

As Boysen Jensen has already remarked (Rep. B. S. 26, 1919, pg. 35) even neighbouring Limfjord-broads offer great differences with regard to the quantitative composition of the sea-bottom fauna. As an instance, 1917 was a splendid *Abra*-year in the Thisted broad (with 265 specimens per 1 m²), but comparatively poor in the Livø broad (50 specimens per 1 m²); in 1923 the case was the reverse, a plentiful brood-year for *Abra* in all Limfjord-broads (for instance 488 sp. of the 0-group per 1 m² in the Livø broad) except Thisted, where it was almost a failure (31 sp. of the 0-group per 1 m²).

The above would tempt one to assume that for each broad the production of brood is confined to its own adult bottom-animals' production of pelagic larvae; this undoubtedly is not correct, as a numerous 0-group may easily grow up in waters where no adults of the particular species are existing; in the Thisted broad in 1910 and 1917, after the spring-valuations had shown no adult *Abra* to exist, there appeared no less than 84 and 265 sp. respectively pr. m² in the course of the summer.*) These can evidently only originate from pelagic larvae, which have come drifting there from other broads. So the explanation is certainly, that while the distribution of the pelagic larvae is almost identical all over the Limfjord, the physical conditions, deciding whether the larvae shall reach the bottom stage or not, varie largely even in adjacent broads, and thus calls forth different results.

In comparison with the food-animals mentioned here the others, *Polychaeta* and different small *Mollusca* only vary slightly, as may be seen from the figures 2—4. The principal Chaetopod is *Nephthys*, mostly *Nephtys hombergi*. The brood probably appears in the course of the summer, as the amount per m² always is highest in the autumn. *Nephthys* is a much sought for fish-food, but here the case is the same as with *Abra*, *Solen* and *Pectinaria* in the Nissum broad, the fishes specially persecute the bigger specimens, which therefore are very rare in the Limfjord. The small specimens are apparently difficult for the fishes to get hold of; even in the Nissum broad the number therefore keeps pretty stable, between 10—20 g per m², in the Thisted broad it varies mostly between 20 and 30 g per m².

*) Boysen-Jensen (l. c. pg. 38) whose opinion it is that a sufficient number of adult individuals always remain at the bottom to produce new broad, points out himself that no *Corbula* existed in the Thisted broad in May 1911, but 162 individuals per m² in May 1912. Notwithstanding he presumes it was only by accident the „bottom sampler" took no Corbula in May 1911, and that all the same there must have been some old individuals left in the broad, as *Corbula* often appear locally, and as „in the said year no *Corbula* broad has arisen in the other Limfjord-broads". However, on looking back at his own statement of brood-years in the Limfjord (l. c., table V. e.) it appears that *Corbula* brood has just been found in all the Limfjord-broads investigated in 1911, in the Kaas-broad — Sallingsund even 450 specimens per m². — *Abra* does not appear locally in the Thisted broad, and when the spring valuations in 1910 and 1917 with 100 and 50 samples respectively have shown no *Abra*, there can be no doubt that there have been none in this broad at the time in question.

Of *Mollusca* the principal species are: — *Mya truncata*, *Cardium fasciatum*, *Philine aperta* and *Acera bullata*. *Mya truncata*, which is only eaten by fish as long as it is below 3 cm in length, has only in 1915, as already mentioned, produced any brood of importance in the Thisted broad; the latter years have been poor brood-years. *Cardium fasciatum* seems to produce some brood regularly every year, but only quite exceptionally have the brood-years been so good for this little bivalve that it has been of any significance in weight per m^2; it is, however, a favourite fish-food. This is also the case with *Philine* and *Acera*, which are specially sought for by the eel; they no doubt as a rule only live one year (two summers, but only one winter) in the Limfjord, as is also the case with *Cardium fasciatum*.

The total amount of fish-food in the three Limfjord-broads varies, as is seen by figures 2—4, between about 13 and 400 g per m^2; the lowest figure originates from the Thisted broad, the highest from the Nissum; notwithstanding the broad of Thisted must be regarded as that of the three broads offering the best conditions for fish, for all the animals here are first class fish-food. In average years the food-quantity in the Thisted broad will balance between about 20 to 40 g per m^2, and Boysen Jensen has (l. c. table II.) calculated the yearly production during 1910—1915 to figures lying between 42 and 77 g (rough weight) per m^2. In the broad of Livø which in many points resembles the Thisted broad, there are sometimes many comparatively worthless *Nucula* and *Corbula*, which are only eaten by the fish in lack of better food, but the other food-animals are all first class, and their quantity also varies round about 30 g per m^2. But the broad of Nissum with its huge quantities of *Corbula* and *Nucula* is poor in first class fish-food; the highest figure is 40 g, the lowest 3 g per m^2. The Nissum broad may therefore be compared to an exhausted grass field, where an excessive number of cattle constantly keeps the grass low, while at the same time the weed thrives luxuriantly.

Comparisons between the variations in quantity of fish-food and the yield of the fishery on the territory in question (see figures 2—4) apparently show very little agreement. This is not suprising, when one takes into account partly the fact that the number of plaice transplanted into the Thisted and Livø broad is not equal every year, partly that statistical reports for such small areas as a separate broad of the Limfjord are bound to be rather uncertain. C. G. Joh. Petersen has treated the statistical reports for the Thisted (and Visby) broad up to 1918 in the Rep. B. S. 26, 1919 pg. 21—22, and here he points out that the big decline in the fisheries in 1916 may be caused by the lack of food animals on the bottom of the Fjord that year which was a very unfavourable brood-year, excepting the previously mentioned local *Mya*; further that the poorest year of all since 1908 was 1917 because no plaice were transplanted that year, and he supposes the abundant growth of the brood of the sea-bottom-animals during the summer

1917 to be caused by the fewness of the plaice. In the Rep. B. S. 29, 1922 pg. 43 an account is given of the statistics of the transplantation and plaice-fisheries in the Thisted and Visby broads up to and including 1921; it will be seen that the transplantation after 1917 did not immediately reach the high figures from 1908—15; also the yield in 1918—21 was comparatively poor with, however, a slight rise in the good brood year 1921. I may add that while the yield according to the statistics declined a little in spite of the increased transplantation in 1922, it increased rather considerably in 1923 and 1924 (in which years still more plaice were transplanted) still however not reaching the high figures of 1908—1915, which probably have been put too high.

In the Livø broad the statistics, in agreement with what is given for the

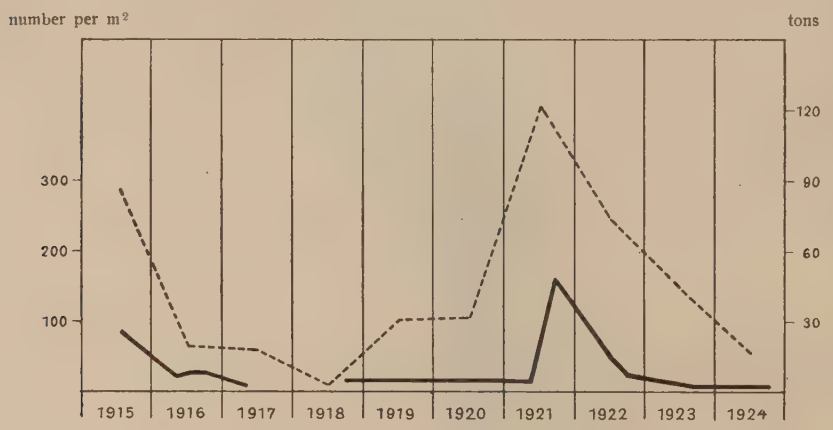

Fig. 5. Fur Sound—Risgaard broad.
Number of *Solen pellucidus* per 1 m².
yield of flat-fish fisheries in tons.

Thisted broad, show its poorest flat-fish fisheries in 1917, when no plaice were transplanted; and the great quantity of food at the sea-bottom in the autumn 1917 may surely be connected with the fewness of the plaice; otherwise the figures for flat-fish fisheries go up and down apparently without connection with the variations in the food-quantities. It must, however, be noted that the years 1918—20, all being comparatively ~~good~~ poor brood-years both in the Thisted and Livø broads, also show poor flat-fish fisheries for both broads. With regard to the western broads, where, as known, no transplantations take place, it must be noted that special good years for plaice fisheries have been proved to occur simultaneously with special good brood-years for the principal food-animals. Thus 1917 gave uncommonly good yield for flat-fish fisheries in the Kaas broad, and simultaneously surprising quantities of *Solen pellucidus* appeared in this broad during the summer. For while May 1917 only gave 13 *Solen* per m² weighing 3 g, October same year gave no

less than 1148 sp. per m² weighing 172,4 g (see C. G. Joh. Petersen, Rep. B. S. 29, 1922, pg. 40). We find a remarkable coincidence between the quantity of *Solen* and the yield of the flat-fish fisheries in the Fur Sound—Risgaard broad. As will be noticed from fig. 5 there is an obvious and hardly accidental correlation between the fluctuation of numbers per m² of *Solen* (the curves for weight of *Solen* per m² carefully follow the curves for number of *Solen*) and the fishery-yields; unfortunately no valuations exist for the autumn 1917 and the spring 1918.

In the Nissum broad it is improbable that one would find any correlation between the amount of fish-food and the yield of plaice, partly because the amount of

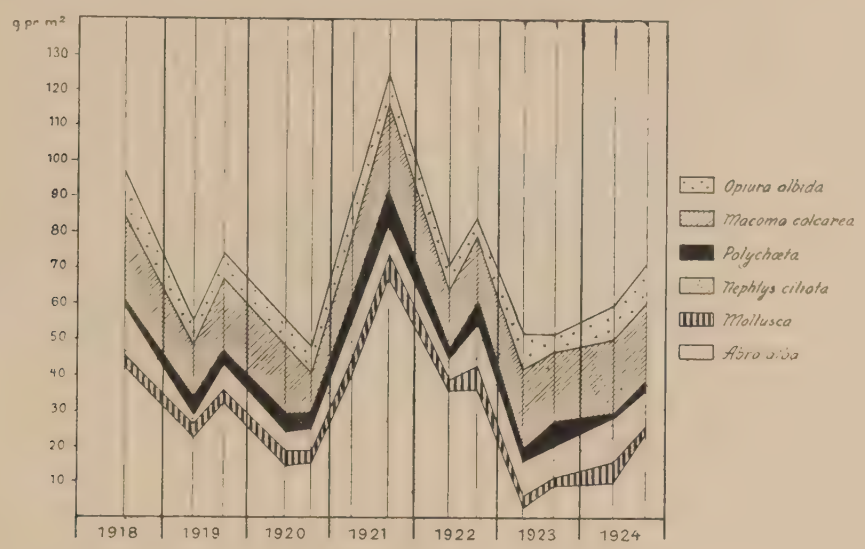

Fig. 6.

Quantity of fish-food in g (rough weight) per 1 m² bottom area North of Funen in the years 1918—24.

food, as mentioned, always is kept on a minimum level, partly because the Nissum broad is a pronounced „wandering place" (C. G. Joh. Petersen in Rep. B. S. 29, 1922. pg. 38) from where the plaice continually wander out to the other Limfjord broads and to where they come in from the North-sea. Fishery-statistics for the Nissum broad during 1910—24 (see fig. 4) proves the plaice fisheries to have given their best yield in 1912 and —13, after which the yield decreased heavily and reached its lowest figure, 8000 kg, in 1916. Looking at the curves for the amount of food it is seen that 1912 was a splendid brood-year for both *Abra* and *Pectinaria*, of which there still remained some in 1913; but in 1914 coincident with the great invasion of *Corbula*, the amount of first-class food animals decreased to a minimum which remained into 1916, so there seems, however, to be some connection. Afterwards there certainly does come an inexplicable rise in 1917—1919

(unfortunately the autumn-valuation of 1917 is missing) and a fall in 1920, but the fact that the curve ends with two summits for 1921 and 1923 agrees very well with the rise in number of first-class fish-food for these two years.

It must, however, be remembered that many other factors than the quantity of food influence the fishery-yield, e. g. the intensity of the fisheries at the different places and in the different years, weather-conditions etc.

When all these conditions, together with those already mentioned (transplantation, inaccurate statistics), are taken into account naturally it is to be expected that the quantity of food and the yield of fishery cannot every year fluctuate correspondingly.

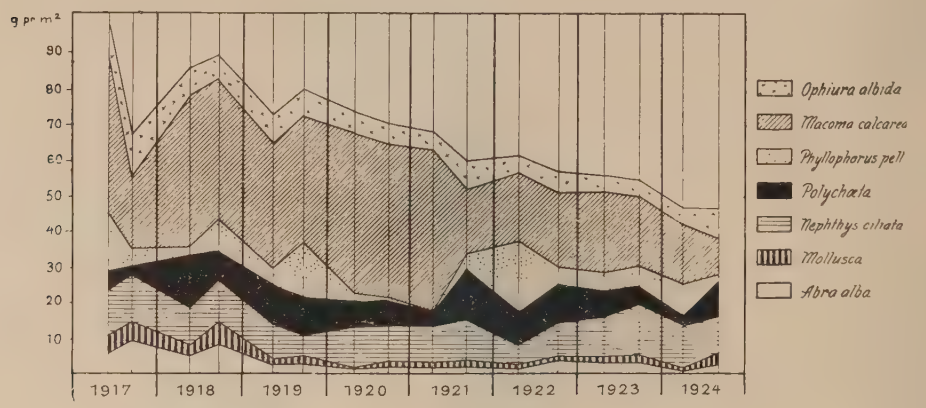

Fig. 7.

Quantity of fish-food in g (rough weight) per 1 m² bottom-area of the *Abra* community between Nyborg and Svendborg in the years 1917—24.

Turning now to the valuations round Funen (Fig. 6—9) we also find the *Abra*-community represented here, but otherwise the conditions differ much from those of the Limfjord. While in the Limfjord there were many different species of small bivalves composing the main part of the food-animals, *Abra alba* is here their only representative; on the other hand, the *Chaetopoda* which play a minor part among the food-animals of the Limfjord are present in great quantities round Funen. First of all this applies to the large genus *Nephthys ciliata*, but there also appear, in addition to different other genera, *Pectinaria koreni* and *Arenicola marina*, often in large quantities. In agreement with this the *Polychaeta* in the waters round Funen are found to compose the main substance of the stomach-contents of the fishes, and much more so than in the Limfjord. Thus the *Polychaeta* constitute seldom more than $^1/_{10}$ of the stomach-contents of the plaice in the Limfjord, but often $^1/_2$ or more in the waters round Funen.

Looking first at the variations in the quantity of food in the large „soft-bot-

tom" area North of Funen*) (fig. 6), it appears clearly from the figure that the only animal varying noticeably as regards quantity is *Abra alba*. The reason for this might be expected to be the eager persecution, to which these animals are subject by the predatory animals (specially the fishes). However, on looking closer at the size and age of the collected individuals, it appears that the consumption of the fishes hardly can have much influence on the stock af *Abra*. Thus the *Abra* in these waters grow much older than for instance in the Limfjord; on measuring and examining the growth-rings on the shells it has been proved that while the individuals even from the best brood-years in the Limfjord as a rule disappear during their second summer, we find a considerable amount of *Abra* in the waters North of Funen, reaching an age of both three and four summers, and this applies to individuals both from good and poor brood-years. The enormous quantity of dead and whole shells of large adult *Abra alba* which cover the bot-

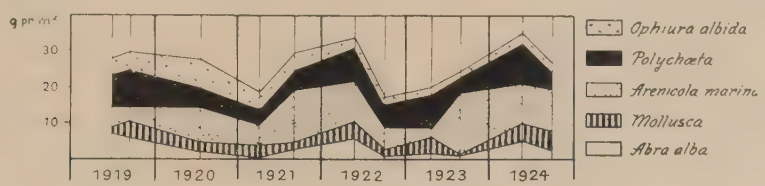

Fig. 8.

Quantity of fish-food in g (rough weight) per 1 m² bottom area of the *Abra*-community between Assens and Faenø in the years 1919—1924.

tom of this last named water proves that a number of individuals die from old age or of purely physical reasons.

Neither do those *Polychaeta* even more persecuted by the fishes show any variations of importance; only there is as a rule a somewhat larger quantity in the autumn than in the spring, the brood of the year having appeared in the meantime.

Neither do the second-class food-animals *Macoma calcarea* and *Ophiura albida*, vary in quantity, and the curve for total quantity of fish-food follows the curve for *Abra alba*.

According to the above, a correlation between the variations in the quantity of food and the yield of the fishery can hardly be expected to be found, as there always seems to be a surplus of fish-food. Neither have I been able to prove such a correlation; furthermore it is impossible to get any correct statement of the yield of the fishery of the areas in question from the fishery-statistics, which

*) Valued each time with 20 samples of 0.1 m², excepting September 1919 (15 samples), June 1920 (18 samples) and September 1924 (17 samples).

only show how much has been brought to the different ports, not stating where the catches have been taken. I have accordingly refrained from reproducing curves for the yields of the flat-fish fisheries, based on figures from the fishery-statistics regarding supplies from the surrounding districts; according to these figures, 1919 seems to have been the best year, 1918 and 1923 the poorest, whereas 1921, which shows up far the largest quantity of food per m^2, only was a medium year.

While the quantity of food North of Funen is rather considerable, varying from about 50—130 g per m^2, of which as a rule far more than one half is first-class fish-food, we find a comparatively small amount of first-class fish-food in the partly „hard-bottomed" *Abra*-community, situated in the South part of the Great

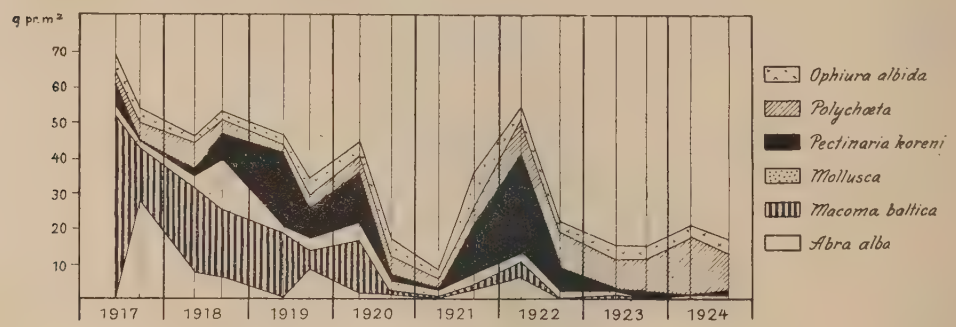

Fig. 9.

Quantity of fish-food in g (rough weight) per 1 m^2 bottom area in the *Macoma*-community between Nyborg and Svendborg in the years 1917—1924.

Belt between Nyborg and Svendborg (see fig. 7), which has been valued each time with 25 samples of 0.1 m^2 each. *Abra* is only poorly represented, whereas the *Polychaeta*, represented mainly by *Nephthys ciliata*, form the main part of the available quantity of first-class fish-food. The second-class food-animals constitute more than half of the total amount and consist of the *Echinodermata Phyllophorus pellucidus* (only eaten by cod) and *Ophiura albida*, and also of large *Macoma calcarea*, which are only eaten by the largest individuals among the plaice. The variations of quantity are comparatively small, as the amount of first-class fish-food keeps to about 20—30 g per m^2, and the total amount to about 60—70 g per m^2.

Also in the *Abra*-community between Assens and Faenø (Fig. 8, valued with 10—20 samples of 0.1 m^2 each time) is found first-class fish-food, mainly consisting of *Polychaeta* (but, in this place, chiefly *Arenicola marina*) which keeps pretty constantly to 20—30 g per m^2; of second-class food-animals there are here only *Ophiura albida*, represented in comparatively small amounts.

A sample of the *Macoma*-community is seen in Fig. 9; the valuations have been carried out (with 20 samples of 0,1 m^2 each time) in the narrow, soft-botto-

med area between Funen and Langeland, where the proximity of the *Abra*-community occasionally is shown by an invasion of *Abra alba*. As shown in Fig. 9 the variations in the quantity of food are considerable. All the food-animals, with the sole exception of *Ophiura albida*, are first-class fish-food, and they separately vary much in weight per m^2 from one valuation and another, reflecting good and poor brood-years. Thus it may be noticed from the Figure 9 that *Abra* has had good brood-years in 1917, 1919 and 1921, *Pectinaria* in 1918 and 1921. Moreover it may be noticed that the quantity of food here, as is the case in the Thisted broad, generally increases from autumn to spring, and decreases from spring to autumn; only in the *Pectinaria* brood-years 1918 and 1921 the weight-figure increases during the summer. The explanation must be the same here as there, viz. that the consumption by the fishes generally takes place during the summer, as these in winter seek the deeper and warmer water outside the *Macoma* community.

Other valuations have been carried out at *Abra* and *Macoma*-localities in the Little Belt, but they only show the same as the above-mentioned examples, and therefore I do no publish them here.

Some valuations have been repeated occasionally in the Sealand archipelago, in the large broad of the Ise-fjord, the northern part of the Great Belt, West of Samsø and, in the Kattegat, on the line Gjerrild-Hals. In the two first places the variations in quantity are considerable; in the Ise-fjord, which in so many ways resembles the Limfjord, they are especially brought about by the *Corbula*, *Solen* and *Pectinaria*, which, in certain years, appear in large quantities, only to disappear again just as quickly. In the northern part of the Great Belt and West of Samsø (*Abra*-localities) the variations are, however, only small, and in the *Venus*-localities of the Kattegat only the *Mactra subtruncata* varies in quantity, as already mentioned, very considerably from spring to autumn.

As a summary of what is mentioned above regarding the quantity of fish-food, it may be stated with respect to the *Macoma*- and *Abra*-communities that in closed waters as the Limfjord, the Isefjord, the Sealand archipelago, the waters between Funen and Langeland, it varies in a very high degree from spring to autumn and from one year to another, but it varies in a lesser degree in open waters, as North of Funen, the Great Belt, West of Samsø and in the Little Belt; it is here only the *Abra alba* which varies in quantity in specially favourable localities. It is principally the smaller species of bivalves which produce the sevariations; among the *Polychaeta* only *Pectinaria koreni* varies in quantity in any noteworthy degree per m^2.

The causes of these variations are the following: 1) Good brood-years alternating with poor; even in adjacent places a pronounced difference may be seen in the quantity of yearly brood of small bivalves or *Pectinaria;* this is thought to

depend on the difference in physical conditions in the respective places during the period when the transition from the pelagic stage to the bottom stage of the animals in question takes place. 2) The consumption by fishes and other *Carnivora* plays an important part, especially in limited areas, as in the Limfjord; however the importance of the fishes' consumption has certainly previously been much exaggerated. 3) Physical reasons, as cold, lack of oxygen etc. often kill large numbers of food-animals. *Corbula* in the Limfjord and Ise-fjord, *Mactra* in the Kattegat are often found in spring with decayed inner parts.

In many cases a connection has been proved between the variations in the quantity of food and the yield of the fishery.

The *Venus*-community in the Kattegat only shows important variations in quantity as regards *Mactra subtruncata*; as yet nothing is known regarding the animal communities which live still deeper; it is to be hoped that future investigations will throw light on this subject.

V.

A Comparison between the Danish Oyster-Beds and those in Holland and the South-West of France.

By

R. SPÄRCK.

In order to investigate the well-known „green oysters" of Marennes, for which purpose I had received a fellowship from the Carlsberg Fund, I spent the months December 1924—January 1925 in the south-west of France. During this stay I had an opportunity of making myself acquainted with the conditions for the oysters there. On my return I also profited by a few days' stay in Bergen op Zoom in Holland for visiting the oyster beds there. In this small paper I shall briefly state some of the most important differences in the surrounding conditions of the oysters in the Danish waters as well as in the above mentioned southern seas, which fully account for the great difference between the yield of the oyster fishery in Denmark and that of Holland-France.

Oyster fisheries at the south-west of France are largely concentrated on comparatively small areas, viz. partly the Arcachon bay a little south of the mouth of the Gironde, and partly the mouth of the river Seudre a little north of the Gironde between this river and the mouth of the river Charente. Besides in these two localities it is in France only in certain parts of Bretagne (Morbihan, Cancale), that oyster fisheries are carried out on a larger scale.

A rather detailed description of both the natural condition and the practice of the oyster-culture at Arcachon was already given in 1910 (J. Hornell: The practice of the oyster-culture at Arcachon. Madras Bur. Fish. Vol. II. Bull. 5. 1910). I shall therefore not enter on any elaborate description here. I only wish to point out that the waters in question are rather small, no more than about 15,000 ha. The oysterproducing part of the Limfjord is considerably larger, more than 100,000 ha. A characteristic point is the small depth in a large part of the bay; ab. 8000 ha. are laid dry at low tide. The oysters mainly occur in these large beds which are laid dry, when the tide goes out. In the western part of the bay i. e. nearest the mouth, the bottom consists of clay more or less mixed with sand; on the exposed parts, where the sandy bottom is loose and shifting, there are no oysters. In the eastern part of the bay the bottom is pure clay. These beds contain besides the oysters a number of other organisms, mainly such

as are buried in the clay or sand, for instance different nther bivalves, as the large razor-shell *(Solen ensis)*, different species of *Tapes*)*, the common cockle *(Cardium edule)* and the sand-gaper *(Mya arenaria)*, this latter however only in the inner parts of the bay. Between these large banks, which cover more than one half of the bay area, there are 10 - 15 m deep channels. Large growths of grass-wrack *(Zostera)* cover part of the slopes tewards these channels.. Abundant animal life occurs in the channels themselves, for instance a rich epifauna of Ascidiæ, Annelidæ etc. One of the most commen bivalves there, is the scallep *(Pecten varius)*, also characteristic in the Limfjord. Hydrographically the Arcachon bay is characterised by its high summer temperature, which is about 22°, and by its tide, the daily difference in flood and ebb-tide amounting to about 3—4 m. The high summer temperature conditions a considerable production of fry and spat every year. In this respect no alteration seems to have taken place as long as a large stock of European oysters *(Ostrea edulis)* was found in the bay. This oyster disappearing from these localities is certainly due to the immigration of another species, the Portuguese oyster *(O. angulata)*, which has a higher growth-rate and appears to be content with a smaller quantity of nourishment and which has accordingly totally competed out the European species. This is not only the case in the Arcachon bay, but also on the entire south-west coast of France, south of the mouth of the river Loire. During the last fifty years the *O. angulata* has quite supplanted the *O. edulis*. The high tide in the Arcachon bay is also of great importance for the oysters there, as the considerable change of water and the circulation caused by the tide, may to a large extent increase the possibilities for the food-supply; and therefore a large number of oysters per unit area are able to grow and live in the Arcachon bay. A continuous layer of *O. angulata* may cover the sea-bottom, without checking or stopping their growth. The essential factors therefore apparently are the high summer temperature conditioning the large production of spat and the high tide which conditions the great density of the stock.

What has been said above regarding Arcachon also applies to the other French south-western oyster area, the Seudre district. It is here the question of a funnel-shaped river-mouth, or rather a bay, the water being salt enough for oysters to exist even about 20 km from the mouth. Outside of this bay there is an island, Ile d'Oléron. Thus a small water is formed here much resembling the bay of Arcachon; calm protected coasts with large banks, dry during ebb-tide. Temperature and tide are about the same as at Arcachon, only the supply of fresh-water is somewhat more abundant, which is assumed to ameliorate the food conditions. In this connection it may be pointed out that these coasts are marshy meadows, inundated at spring-tide, from which a considerable supply of organic substance probably flows to these waters.

*) Very frequently were *T. aureus* and *T. pullastra*; besides *T. decussatus* occurred.

These two localities have particularly good conditions of temperature and nutrition in common. It is therefore comprehensible that it has been possible in spite of the small area to gather about ten times as many oysters here as during the best periods in the Limfjord even without artificial culture, and that a still much larger production has been obtained by culture, from Arcachon alone in some years 500 millions annually.

Also in Holland it is actually only a very limited area, much of the same size as the above mentioned, which produces about all the oysters taken, viz. certain parts of Ooster-Schelde. Ooster-Schelde is not, as might be gathered from the name, the mouth of a river but a number of arms of the sea, cut off from Wester-Schelde by a dam, so that no water from the Schelde flows directly into Ooster-Schelde. Oyster fisheries are carried on in the inner, slightly widening part of the Ooster-Schelde head arm, between the continent and the islands Tholen and Zuid Beveland; some fishery is also going on further north at Grevelingen between the islands Schouwen and Over Flakke. The latter locality receives a large supply of fresh water (Rhine and Maas), sometimes so abundant that many oysters are killed thereby; generally it applies to the Dutch oysters beds that the degree of salinity of the water is rather small, rarely much above 25 $^0/_{00}$, about the same as at the limits for the extension of oysters in the Limfjord. In accordance herewith the Dutch oyster is as a rule but small in comparison with the Limfjord oyster. The spat settles principally in the former locality, where the depth is small, at low tide only a few metres, but still larger than at the French coast, for in Holland oysters only rarely lie dry at ebb-tide. The tides are high here, about equal to those at Seudre and Arcachon. The result is also somewhat similar, the production per unit area being considerably higher than in the Limfjord, as far as information could be got 20—30 oysters per m², therefore not so much as in south-west of France; in Holland the question is however of European oysters, which are much more difficult to feed than the Portuguese oyster now living at the south-west coast of France. According to information kindly rendered me by Dr. Folpmers in Bergen op Zoom, the oysters of Grevelingen in some places covered the bottom exactly as in France; this seems to have been more than the existing quantity of nouriskment permitted, as the great mortality in Holland some years ago was, according to Dr. Folpmers, due to too large a production per unit-area. The fishery yields, which have been as high as about 50 million oysters annually, have now decreased to 15—20 million a year, but still give more than double the amount of what the Limfjord has rendered during the best years there, and it must further be remembered that the size of the Dutch oyster-producing areas are only $^1/_5$ of the corresponding areas in the Limfjord. A second important factor, the summer temperature, is given as being ab. 20° at the Ooster-Schelde, sometimes a little higher, seldom less than 17°—18°. As long as we have carried on observations regarding the temperature in the Limfjord, we have only one year (1914) had above 20° for any length of time, and the temperature rarely reaches

17°—18°. As regards these conditions, the Ooster-Schelde thus is much more favourable for the oyster, and it is therefore evident that there can be no great scarcity of spat here. While the number of spat in the Limfjord during the latter years has been considerably smaller than the number of large oysters, the case is the reverse in Holland, where more small oysters than large are fished.

To all the three here mentioned oyster producing areas it is therefore applicable that they are situated in small, protected, shallow, lagoon-like bays with a summer temperature considerably higher than that of the Limfjord, with a far stronger renewal of water, caused by the tide, and as regard the Seudre district and the Dutch localities, with a rather abundant supply of fresh water. Comparing these areas with the Danish oyster localities, we find the Limfjord to be the place which in most respects recalls the above, also here we have rather shallow lagoon-like broads, though much larger than the French and Dutch, the summer temperature, compared with other Danish waters, is high, though not high enough for so extensive fisheries as those of Holland and France. On account of the low winter temperature and the considerable growths of grass-wrack along the coasts of the Limfjord, the main part of the oyster stock in the Limfjord is to be found at depths of from 5—8 m, i. e. deeper than the above mentioned West-European beds. Further no great renewal of water takes place in the Limfjord as the tide is lacking, the production per unit area is very poor, these being rarely more than one oyster per 1 m² on natural beds, and experience has taught us that on the artificial beds a density of more than a few oysters per 1 m² is not favourable. In spite of the small productiveness per unit area the Limfjord would be able to contain a considerable stock of oysters, if sufficient numbers of young oysters could be procured, as the areas at disposal are very extensive. Further the fauna of the Limfjord, for instance the occurrence of the previously mentioned scallop *(Pecten varius)* and the comparative frequency of a species of Tapes *(T. pullastra)*, show the Limfjord to be the only Danish water where the natural conditions do to some degree recall those of the mentioned West-European localities. Considering our conditions the Limfjord may be stated to have had a rather large stock of oysters. With our low summer temperature we cannot expect to have as large a stock as those of Holland and France, and even with a supply of young oysters or with artificial breeding we would not be able to reach the same density as there. This means that we shall probably never be able to fish as cheaply as in Holland and France, as we shall always be forced to spread the oysters in the Limfjord over a far larger area. The far distances in the Limfjord in connection with the greater depths effect much difficulty as regards the minute supervision, cleaning etc. carried out on the oyster areas in Holland and the south-west of France.

When turning from the Limfjord to the oysters in the Kattegat I will not give any detailed mention of these latter but refer to my treatise on the biology of the oyster (Rep. Biol. Stat. XXX); I shall only point out that the oyster there

lives under still more unfavourable conditions of temperature and on greater depths than in the Limfjord. In accordance herewith the stock is still scarcer and the possibilities for fishery minimal. The third Danish oyster locality, the sea at the west coast of South Jutland, is in one single respect more like the West-European localities than the Limfjord, as it has a considerable tide. There seems however, to be a lack of sufficiently calm places with favourable bottom conditions; but where such are available there would probably, according to the scarce information to hand, be good conditions for the development of a dense stock of oysters; such places are however rather few and not extensive, so that any possibilities for large oyster fisheries are hardly to be expected there, while on the other hand the possibility of practising an oyster culture according to Dutch and French methods in certain places at the southwest coast of Jutland cannot be totally excluded. For what must be demanded, if such an oyster-culture is to be carried on with many oyster farmers, each possessing quite a small area, is just the possibility of breeding many oysters on a small area; preferably also shallow water and short distances to the oyster beds, whereby the fishing is facilitated. All this is wanting in the Limfjord; even if it should be possible to supply a considerable amount of young oysters annually it would still be difficult to adopt exactly the same methods as in Holland and France, for in spite of some resemblance the natural conditions are too different.

In summing up the results of this comparison it is evident that all our oyster localities, as regards hydrographic conditions, are essentially worse circumstanced than those in western Europe, and that the conditions of nourishment, excepting perhaps West Slesvig, are poorer, so that no such large production per area unit can be expected as in western Europe. The fisheries in the Limfjord will therefore always be more difficult, more expensive and more uncertain than in Holland and France, even with more favourable breeding conditions. The comparison confirms the great importance of hydrographic and food conditions. The bad state in which our oyster fisheries in the Limfjord at present are, can fully be explained by the fact that the increase has been too little in proportion to the decrease, on account of the unfavourable hydrographic conditions. The bad state in West Europe, in Holland as well as in the south-west of France is evidently called forth by the food conditions, either a foreign food competitor *(O. angulata)* having immigrated, or too large a production per area unit having caused mortality on account of insufficient nourishment. The supposition held forth in my above mentioned treatise (pg. 75) regarding the cause for the oyster-mortality in West Europe to be food-difficulties, seems to me to be further corroborated by my observations in Holland and France, though they are as yet far from being proved.

IX. Trawlings in the Skager Rack and the Northern Cattegat in 1897 and 98. 1899. 56 pg. With one Map.

X. Fortegnelse over Aalerusestader i Danmark etc. — Mindre Meddelelser. 1899 og 1900. 36 pg. Et farvetrykt Kort. (1900—01.)

X. List of The "Aalerusestader" in Denmark, etc. — Smaller Communications. 1899 and 1900. 37 pg.

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XII. I. Where, and under what Conditions, can the Eggs of Plaice be developed into Young Fish within the Skaw? II. On the Young Stages of the genus *Zeugopterus*. (With one Plate.) III. Can we enter into Competition with the Foreign Steam-trawlers in our Seas outside the Danish Territorial Limit. 1902 and 1903. 33 pg.

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XV. Studier over Østersfiskeriet og Østersen i Limfjorden. Med et Kort, Temperaturkurver, 3 Tabeller og 2 Tekstfigurer. 1907. 70 pg. (1906—07.)

XV. I. First Report on the Oysters and Oyster Fisheries in the Lim Fjord. (70 pg.) 1908.

XVI. (Aalegræssets (*Zostera marina's*) Vækstforhold og Udbredelse i vore Farvande. 1908. 61 pg. (1906—07.)

XVI. On the Ecology and Distribution of the Grass Wrack (*Zostera marina*) in Danish Waters. With 9 figures.) 1908. 62 pg.

XVII. Studier over Østersfiskeriet og Østersen i Limfjorden. 1908. 24 pg. (1906—07.)

XVII. II. Second Report on the Oyster and Oyster Fisheries in the Lim Fjord. 1908. (24 pg.)

XVIII. I. Om Udbyttet af Limfjordens Fiskerier i de senere Aar samt om Rødspætteudplantningen i 1908. Med 6 Tabeller og 1 Kort. II. Biologiske Undersøgelser over Limfjordens Rødspættebestand. Med 3 Tabeller. III. Om Rejefiskeriets Udbytte fra 1885—1907 og dets Forbedring ved Fredning. Med 3 Tabeller. 25 pg. 1909.

XVIII. I. The Yield of the Limfjord fisheries in recent years and the transplantation of plaice in 1908. With 6 tables and 1 Chart. II. Biological investigations on the stock of plaice in the Limfjord. With 3 tables. III. The Yield of the Prawn fishery from 1885—1907 and its improvement by means of protection. With 3 Tables. 25 pg. 1909.

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XXI. Valuation of the Sea. II. The animal communities of the sea bottom and their importance for marine zoogeography. With 6 Plates, 3 Charts and an appendix. 42 + 68 pg. 1913.

Selvstændige Publicationer.

XXII. I. Studier over Havbundens organiske Stoffer. II. Undersøgelser over Næring og Ernæringsforhold hos Havbundens invertebrate Dyresamfund i danske Farvande. III. Om Biologisk Stations Virksomhed fra 1889—1914. Med Illustrationer og Tabeller. 132 pg. — A. Tillæg. Analyser af Mave- og Tarmindhold. 45 pg. B. Tillæg til Beretning XXI fra Den danske biologiske Station. Med to Kort. 6 pg. Om Dyresamfundenes Udbredelse paa Havbunden. 1914.

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XXV. The sea bottom and its production of Fish-food. A survey of the work done in connection with valuation of the Danish waters from 1883—1917. With 12 Plates and 1 Cart. 82 pg. 1918.

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XXX. Undersøgelser over Østersens *(Ostrea edulis)* Biologi i Limfjorden, særlig med Henblik paa Temperaturens Indflydelse paa Kønsskiftet. 82 pg. 1924.

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